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FOOD TECHNOLOGY

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FOOD TECHNOLOGY

Official Publication of
The Institute of Food Technologists

C. OLIN BALL, *Editor*
G. J. HUCKER, *Managing Editor*

EDITOR'S NOTE

The Council of the Institute of Food Technologists, in its last meeting of 1946, decided that the Proceedings for 1946 would not be published as such but that the Proceedings, News Letters, and Transactions would be combined to form an Institute journal. FOOD TECHNOLOGY is that journal.

The editor assumed his duties late in December. Because of the many reasons for inaugurating the issuance of FOOD TECHNOLOGY early in 1947, it was decided not to delay the first number until the formulation of an Editorial Board could be completed. We regret our inability to announce the composition of the Board in this issue. This space, in future issues, will contain a list of the names of Associate Editors.

Subscriptions. Price: $10.00 per volume in North and South America; $10.50 in all other countries. Prices are net, postpaid. New subscriptions and renewals are entered to begin with the first issue of the current volume. Renewals should be made promptly to avoid break in series. Subscriptions should be sent to The Institute of Food Technologists, Geneva, N. Y. Subscriptions at no cost for all members of the Institute of Food Technologists.

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FOOD TECHNOLOGY

VOLUME 1 JANUARY, 1947 NUMBER 1

Editorial

FOOD TECHNOLOGY is presented to the members of the Institute of Food Technologists, and to others, in the best interests of the food processing industry. Its contents will include primarily the results of technical research in food processing, together with such general information as the Editorial Board may deem pertinent to the interests of the membership and of the industry as a whole.

FOOD TECHNOLOGY will include, for the present, the information heretofore included in the Proceedings and News Letters and that proposed for the Transactions of the Institute, in addition to editorials. It is hoped that other sections will soon be added.

The officers of the Institute acknowledge a deep obligation to the members whose foresight and loyal support have made possible the rapid expansion of the Institute to better serve the processing industry. An increased contribution to the industry through the spreading of basic and practical information is foremost among the long-range objectives of the Institute.

FOOD TECHNOLOGY aims to attain that objective.

Food Technology Curricula

While the constitution of the Institute defines a "Food Technologist" and indicates the subjects in which he should receive instruction in colleges and universities, there is still great lack of uniformity in food technology curricula and requirements for graduation in American educational institutions. The Institute of Food Technology can do much to assist educators in formulating courses of instruction and in promoting better correlation of instruction of one institution with that of others.

Our Committee on Education is attacking a most commendable project and is laying the foundation for the presentation of a well considered program of instruction to the various college and university departments of food technology. The writer was a member of I. F. T.'s first committee on food technology curricula, and on the basis of that committee's work and as a result of thirty years' experience in this field, several suggestions are offered.

First, it is likely that a thorough training in the sciences and engineering basic to food technology can not be given or absorbed in less than five years. M. I. T.'s step in that direction is very commendable.

Second, because modern food handling and processing involve many phases of engineering it is highly desirable that the prospective food technologist obtain considerable instruction in mechanical engineering plus the mathematics required for such courses.

Third, he should be able to express himself effectively by both the spoken and the written word. He may get some of this training in high school, but should supplement it with college courses in written and oral expression, preferably in subjects pertaining to food technology.

Fourth, he should in some manner gain considerable food processing ex-

perience, either by vacation jobs in food plants or by instruction in operating pilot-scale equipment in the university or college.

Fifth, it goes without saying that he requires thorough training in chemistry and bacteriology, much beyond the sophomore year. This should include physical, industrial, advanced organic, advanced inorganic and colloid chemistries plus at least two years of microbiology.

Sixth, in his fifth year he will gain experience in research in order that he will not be helpless when the boss fires a problem at him.

Such a curriculum may require five years of exceedingly tough study, but the results will be worth it.

W. V. Cruess

Freezing Preservation of Foods—The Future

It is always necessary to think of the future, in any field of human activity. The better the thinking, the fewer and less costly the mistakes will be. Current thinking on the future of frozen foods ranges from the optimistic type which sees six or more billions of dollars worth of frozen foods produced in the United States annually within a few years, to the pessimistic type of thought which views frozen foods as a costly and impermanent fad. There seems to be more optimism than pessimism right now.

If the optimists are right, then we can expect to be eating a fairly large share of our foods from zero cabinets within the next few years. Much of our meat, poultry, and fish will come to us in consumer-size, frozen packages. In some regions and in some seasons the fresh will be more economical than the frozen product, but large quantities will be frozen and we will become accustomed to steady consumption of frozen fish, poultry and meat. The optimists are slightly less confident of fruits and vegetables. Frozen fruits and vegetables must face keener competition, from both fresh and canned product, than frozen meats and fish must face. Because of this competition, it may be less easy to reach mass production of frozen fruits and vegetables than to reach mass production of frozen meats and fish.

The pessimists—those who remind us that fads come and go—can point to price, the dependence of most frozen pack on extremely high quality, and the need for extreme care in handling frozen food. They admit (most of them) that a processor of fruits and vegetables may be able to freeze his highest grade of product and then can or otherwise process the inevitable bulk that will be lower in grade. Many, however, just can't see freezing as a means of preserving most of the food that comes from a field or an orchard—or from a herd or flock.

Without going too far into this subject, let's admit that pessimism and caution are very good for all of us, in appropriate amounts. Certainly the family with even low income will occasionally want to buy high quality fresh frozen fruits and vegetables. Certainly they will be able to buy large amounts of frozen poultry, meats, and fish. But the prospect of the day when the great bulk of our nation's food is preserved by freezing still remains somewhat visionary.

Food technologists are by scientific nature inclined to be slightly negative (that is, slightly pessimistic) or, at most, neutral in their thinking about the future. They never admit that a technical problem cannot be solved. They have solved many problems of a

technical sort, however, which, for one reason or another, have not resulted in wide application. On the other hand, they have provided the fundamental basis for our great food industries of today.

Technologically, some important areas in the broad field of frozen foods still remain to be thoroughly explored, mapped and exploited for industrial benefit. These include the development of varieties and types of animal and vegetable produce specifically adapted to freezing preservation, the design and creation of harvesting and field handling equipment in which refrigeration from the moment of harvest or slaughter is an integral part, sounder methods of enzyme inactivation in fruits and vegetables by electronic or other means prior to freezing, the creation of industry standards of quality and bacteriological standards for product and sanitization of plants, the development of protective container types which lend themselves readily to mechanization flow lines in plants, enlargement of our knowledge of ice formation in its relation to many types of tissues and substances (this knowledge to serve as the basis for design of fundamentally sound, efficient and productive freezing equipment), and better transport facilities considering not only design, construction and operating possibilities but the needs of the frozen product.

Physics, chemistry, biology, and engineering must be joined in the minds of those concerned to enable the human brain to study the problems as integrated parts of the whole—not as isolated phases having no bearing on each other.

The engineer must not develop freezing equipment without an understanding of the biological happenings in the products he seeks to reduce to the frozen state. The plant breeder needs direct understanding of what the product is for, how it will be handled and processed, and which characteristics, such as yield, color, growing habits, disease resistance, are required. The plant research and control individual must be alert to more than the problems of plant and process operation and must have an appreciation of the marked influence of raw material character on the nature of the finished product.

Food technology, as defined by the Institute, is the joined endeavors of the sciences and engineering. This definition is sound and must be implemented in action by everyone concerned with the development of the several food industries, among which the young but rapidly growing frozen food industry is included.

H. C. Diehl

THE ROLE OF ANTIOXIDANTS IN FLAVOR PROBLEMS[1]

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Flavor problems in food products arise from diverse contributing factors. An important factor in many instances is the extent and rate of chemical change of the fatty constituents. Not all of the fat changes associated with flavor problems can be ascribed to oxidative reactions which presumably are inhibited or retarded by the presence of antioxidants. While many studies have been carried out relating flavor development to oxidative reactions, only meager data are available on food products containing fat. In the present paper, an attempt is made to summarize some of the fragmentary information on a few types of foods.

During the course of oxidative reactions in the fat constituent of foods, it is widely held that peroxides are formed and eventually also a large variety of scission products. Flavor changes accompany their production.

Antioxidants are substances that delay or retard the oxidation of fats. They vary widely in chemical structure but have two common characteristics: (1) the most effective compounds are phenols with some type of oxygen linkage in the ortho and para position, or both, to the hydroxyl groups, and (2) they all function to relieve fatty acid peroxides of excess energy, thereby preventing for a time peroxide accumulation and flavor change. A host of di- and polybasic organic acids act synergistically with phenolic antioxidants, thereby enhancing their effectiveness.

The resistance of a fat to autoxidation and its accompanying flavor change is usually measured in units of time under certain specified conditions. This period of resistance is commonly referred to as the induction period, and is a relative measure of the stability of the fat or fat-containing food product. Therefore, the over-all function of the antioxidant, whether present naturally or added subsequently in the fat or food, is to prolong the induction period.

When changes in flavor in edible food products, particularly those resulting in a rancid taste, are the direct result of oxidation, the following representative antioxidants have proven of benefit: nordihydroguaiaretic acid (NDGA), esters of gallic acid, particularly ethyl and propyl gallate, thiodipropionic acid, and the tocopherols. The latter occur naturally in a large number of vegetable fats, and in many instances their presence explains the preferential stability of some fats when compared to other vegetable and animal fats of similar type and degree of unsaturation.

Flavor changes may also be produced in a fat or fat-containing food independent of oxidation or independent of appreciable accumulation of peroxides. Since tallowy flavors and odors are most probably a result of decomposition of peroxides rather than the presence of peroxides, the amount of peroxides present when talliness occurs does not necessarily have any meaning. Flavor changes may be induced by hydrolysis or by microbial action. It is fairly obvious that antioxidants would not be very useful in preventing or retarding flavor changes of these types. Perhaps one of the most significant types of off-flavor development in fats is that frequently described as "flavor reversion" and which usually develops prior to rancidification. The term is a misnomer in the sense that most fats given to reversion, other than fish or marine oils, develop odors and flavors in the reverted state which bear no resemblance to the original odor and flavor of the unprocessed fat. It also is apparent

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 16, 1946.

that the objectionable odors and flavors variously described as fishy, painty, beany, grassy, hay-like, straw-like, etc. produced in those fats, hydrogenated and unhydrogenated, and susceptible to reversion, require little or no oxygen for their production. Hence, the use of antioxidants is of small avail in delaying the onset of flavor reversion. Although many theories have been advanced to account for reversion in reverting oils such as fish, linseed, and soybean, none has been found entirely satisfactory nor have adequate methods been developed to prevent it. One striking fact, however, stands out with reference to reverting oils. They all contain linolenic acid. Whether or not the causative agent in the reversion of oils is in some manner related to linolenic acid, the development of off-flavors in the same oils hydrogenated to a degree suitable for shortenings and margarine still requires a satisfactory explanation.

The same kind of flavor deterioration of considerable concern to the fat industry is that present in reverted soybean oil and its hydrogenated product, particularly the latter. The reverted flavor and odor of a hydrogenated soybean oil is distinctly hay-like or straw-like, very unpleasant, and is often carried into a food product, particularly during frying or baking. It may be pointed out, however, that when the percentage of soybean oil in an all-hydrogenated shortening or margarine does not exceed a certain critical proportion of the whole, reverted flavors are difficult to detect. Reverted flavors may also be detected in full-fat soybean flours and very frequently are carried into baked products in which they may be components. Although antioxidants and other preservatives may be used to retard the onset of rancidity and its accompanying characteristic taste, they have proved to be ineffectual in eliminating the peculiarly unpleasant flavors associated with reversion.

A great deal of effort has been made by the shortening industry and the Subsistence Research Development Laboratory to delay the development of rancid flavors in shortenings and other hydrogenated products subsequently to be used in other food products. Nordihydroguaiaretic acid (NDGA) has been found to be an improvement over lecithin, formerly used in overseas lard, in stabilization against oxidative rancidity. However, nordihydroguaiaretic acid (NDGA) when used at levels greater than 0.02 percent in lard results in the development of flavors somewhat bitter and metallic.

The development of oxidized flavor in dry whole milk as it is now produced has been overcome to a large extent. Antioxidants and synergists which have been investigated for stabilizing dry whole milk for the elimination of oxidized flavor include combinations of d-isoascorbyl esters with α-tocopherol and lecithin, wheat germ oils, sodium glutamate, propyl gallate, thiodipropionate, quercetin, an inverted sugar, phosphoric acid, and nordihydroguaiaretic acid (NDGA). All of the antioxidants of a phenolic character and those with d-isoascorbyl combinations exercise an inhibiting action on off-flavor development in dry whole milk when stored at room temperatures. The product behaves comparably to samples gas-packaged at a level of about 3 percent oxygen. None of the antioxidants are of value in eliminating oxidized flavor in dry whole milk when stored in air for a period of one year at temperatures of 90°, 100°, and 110° F.

The problem of protecting dry whole milk powder from a stale flavor or heated flavor appears to be independent of that associated with rancid flavor. The development of staleness has been found to be directly related to increases in moisture above 1 percent. The development of both stale flavor and heated flavor are also directly related to time and temperature of preheating the fluid milk. Thus, by reducing the time and temperature of preheating, the heated flavor can be eliminated and the stale flavor inhibited. This treatment, however, decreases the resistance of the

milk powder to oxidative deterioration. Although processing methods tend to control stale flavor and heated flavor, antioxidants would have little or no effect except in controlling the development of oxidized flavor.

The unpleasant odor and flavor in rancid fish flesh is very frequently accompanied by changes in appearance of the tissue, such as loss of color or bleaching, and rusting or browning of exposed fatty tissue. Loss of moisture and the development of rancidity and accompanying rust are the principal causes of deterioration in frozen fish. Two distinct actions seem to be involved in the formation of rancid fat in fish, with its accompanying development of off-flavor and odor, the more important of which is spontaneous oxidation of the fat. This action is in most cases accelerated by traces of heavy metals such as iron and copper. In packaged fish, where large areas of flesh are exposed, the retardation or elimination of rancidity is of paramount importance in storage. The use of antioxidants to increase the storage life of fish centers around at least two general methods of application. First, an antioxidant is dissolved in a carrier of edible fat of a type solid at room temperature and relatively resistant to oxidation because of its chemical nature. The fish, after completion of the normal salting process, are dipped in the liquid fat which upon cooling forms a thin solid fat coating. During storage, the fish oil upon liberation from the fish, is absorbed into the coating and thus obtains the benefit of the protective action of the antioxidant. Coating the fish with a film of vegetable fat containing 0.3 percent of nordihydroguaiaretic acid (NDGA) has demonstrated that this technique is effective in delaying rancidity and rusting in frozen fish.

Brine-cured herring, treated with cocoanut oil containing nordihydroguaiaretic acid (NDGA) and packed in brine with added benzoate, remain in excellent condition with very little change on storage at 40° F. for approximately two months. Rancidity develops in untreated control samples during this time, and the flesh darkens slightly. The treated fish are much superior in appearance.

A second method involves somewhat the same technique except that the antioxidants are dissolved in water or brine in a concentration of 0.25 to 0.5 percent and this solution subsequently used as the dipping bath. The fish are dipped in the solution for one minute, drained, then wrapped in cellophane for storage. Of all the antioxidants tested by this method, which included ascorbic acid, thiourea, lauryl thiodipropionate, gallic acid, ethyl and propyl gallate, the last named two, both very fat-soluble, were the most promising and apparently the most effective in delaying the onset of rancid flavors in fish.

The development of rancidity in meat and meat products is one of the limiting factors in their storage. Although refrigeration has solved many problems in connection with this difficulty, appreciable quantities of these products spoil because of oxidative deterioration

Although smoking seems definitely to retard the onset of rancidity in cured meats, the curing ingredients definitely enhance the tendency of meat products to become rancid. Fresh meats can be stored at freezer temperatures for relatively long periods of time, but cured meats are much more susceptible to off-flavor development under the same conditions.

Recent studies on sliced bacon dipped in hydrogenated vegetable oil containing 0.02 percent nordihydroguaiaretic acid (NDGA), and in a hydrogenated vegetable oil containing 0.06 percent d-isoascorbyl palmitate, 0.06 percent soybean lecithin, and 0.01 percent mixed tocopherols show that unsmoked bacon is stabilized four to five times as long as the untreated samples and that smoking and treatment with

antioxidants keep the bacon five times as long as that with no treatment. Gum guaiac has also been effective in the retardation of a rancid taste in bacon. Tallowiness in dehydrated pork can be somewhat retarded by using 0.05 percent gum guaiac.

The fat of pork, dehydrated or non-dehydrated, is more susceptible to fat oxidation than beef or lamb fat. Stabilization of dried pork by the use of a 20 percent alcoholic solution of gum guaiac mixed with the meat produces a product of considerable improvement in taste and flavor over that loosely packed and unstabilized, although it has been found that antioxidants are not essential when the meat is well packed in vacuum-sealed cans.

The stability of animal tissue has been enhanced through the feeding of diets containing such materials as the tocopherols. Positive increases in stability have already been demonstrated experimentally by this means for rats, chickens, and turkeys. Work now in progress in several laboratories seems destined to provide a better understanding of the factors which influence tissue fat stability.

The problem of flavor deterioration in cereal and baked products is not too well understood. Many factors other than fat oxidation are involved in the production of rancid and stale flavors. Many studies have been carried out on the addition of various antioxidants to shortenings which were subsequently to be used in baked products, to determine the antioxidant carry-over effect in the final product. Results have been promising in some instances, and in others have shown no effect. Oat and oat-flour extracts were found to have only a slight favorable effect on the keeping qualities of crackers. On the other hand, nordihydroguaiaretic acid (NDGA) incorporated into a lard used in making pie crusts and crackers exercises some stabilizing effect. Propyl gallate exerts a stabilizing effect on lard, but practically none on crackers baked with the lard. The antioxidant effect of gum guaiac seems to be well carried over into the baked product after incorporation into the lard used as shortening.

The foregoing discussion has served to indicate that the role of antioxidants in flavor problems of food products is not now too well understood. Perhaps a better understanding of the function of these compounds in flavor changes, whether associated or not associated with oxidative rancidity, will be the result of future intensive and cooperative research in this field.

"SHELF-LIFE" OF LOW-SOLIDS GRAPE GELS [1,2]

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AND

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"Shelf-life" of packaged food products has an important bearing on their value. The acceptability of packaged products is dependent on their color, flavor, and physical characteristics. Every manufacturer, storekeeper, and consumer knows this from practical experience. Gelled fruit and vegetable juices are no exception; color, flavor, and general physical characteristics must be acceptable when manufactured and must remain so over the period of time required for normal marketing. Low-solids gels made from low-methoxyl pectinates are still an almost unheard-of product, but, when available, they will fall into the classification of packaged, gelled food products. They must undergo several years of trial in order to determine the "shelf-life" of the different types before they can be accepted for retail distribution. The present report and discussion considers an initial study which has been made of the "shelf-life" of 30 percent soluble solids grape juice gels where the gelling agents were citrus and apple pectinates of low-ester content.

DESCRIPTION OF THE GELLING AGENTS

The two gelling agents used in preparing the low-solids gels were pectinates of the same grade (170) on the 65 percent soluble solids basis, but differed slightly in methoxyl content and in the method by which the methyl ester had been removed. The citrus pectinate was obtained through the courtesy of the California Fruit Growers' Exchange. It was an alkaline-demethylated product having a methoxyl content of 4.4 percent. The apple pectinate was prepared at the Eastern Regional Research Laboratory under a cooperative agreement with the Delaware Agricultural Experiment Station, but was subsequently dissolved, clarified, and reprecipitated as described on p. 7 of Bulletin 246 *(1)*. It was an acid-demethylated product having a methoxyl content of 4.7 percent.

DETERMINATION OF CALCIUM TOLERANCE OF PECTINS

The calcium tolerance of each of the pectinates at the 30 percent soluble solids level was determined in the presence of grape juice. The tolerance has been found to vary for different juices. The method of determining calcium requirement, which is simple, but rather time-consuming, can best be described through the following example in which grape juice (16 percent soluble solids; pH 3.1; relative viscosity of 1.4; no pectin present in juice) was used:

Three-fourths of a gram of the citrus pectinate was mixed with five grams of granulated sugar and stirred into 50 ml. of the grape juice. The mixture was heated to 190° F. and then another mixture (also at 190° F.), with 18.38 percent $CaCl_2 \cdot 2H_2O$ solution as the variant and 10.5 grams of granulated sugar in 35 ml. of the grape juice, was combined with it with constant stirring. The total weight was readjusted to 100 grams with water. The temperature was maintained at 190° F. until poured into the glasses.

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[1] Published as Miscellaneous Paper No. 9 with the approval of the Director of the Delaware Agricultural Experiment Station. Contribution of the Department of Chemistry, February 1, 1946.

[2] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 16, 1946.

The typical results for several varying amounts of calcium chloride solution are as follows:

Calcium chloride, ml	0	0.2	0.4	0.6	0.8	1.0
Gel strength (cm. water pressure)	9	22	39	84	100	90
pH of gel	3.12	3.06	3.02	3.01	2.98	2.96
Setting temperatures, °F.	80?	100	120	130	140	150

The gel strength increased to an optimum and then decreased with an excess of calcium due to coagulation and precipitation tendencies. Excess calcium caused syneresis. In some instances, no calcium will be required. Calcium chloride has a slight effect on pH as may be noted from the above example. Setting temperatures increased as conditions for coagulation and precipitation were improved. Experience with larger batches of gel indicate that it is best to use not more than one-half to two-thirds of the amount of calcium required for optimum gel strength in the laboratory otherwise pregelation or curdling may occur.

The above method of determining calcium tolerance is applicable for gels of any desired sugar concentration provided the soluble solids are adjusted accordingly during the experimental trials.

GEL FORMULAS

As a result of the small-scale laboratory trials, it was found possible to use the same formula for both the citrus and apple pectins. Grape juice gels containing approximately 30 percent soluble solids were made using these pectins, granulated sugar, calcium chloride, and grape juice. The grape juice (pH 3.1) contained 16 percent soluble solids, but had no pectic gel value. The gels were made up on May 10, 1944, from two solutions as follows:

A. Mixed 60 grams of pectinate with 350 g. sugar and stirred into 4300 ml. of Concord grape juice. Heated to 190° F. in a steam-jacketed kettle.

B. Added 50 ml. of 18.38 percent $CaCl_2 \cdot 2H_2O$ and 900 g. sugar to 2600 ml. of grape juice. Heated to 190° F.

Poured "B" into "A" slowly and with constant stirring. Maintained temperature at 190° F. until poured into glasses. (The glasses were Hazel Atlas #2750, 5 oz. tumbler, with 63 mm. plate caps and enamelled "Seal-All" discs to fit.) The glasses were sealed and then turned upside-down for a few seconds so that the hot liquid made contact with the sealing disc. The gels were allowed to set for two days, then packed and shipped by express from the factory of the American Preserve Company in Philadelphia to the Delaware Agricultural Experiment Station in Newark, Delaware. They were placed in storage under conditions which would approximate those of the "store-shelf" (65-100° F.)

EFFECTS OF STORAGE

Sample gels were examined at various intervals and the effects of aging determined over a 17-month period of storage. Indices used were general appearance, flavor, gel-strength, pH, tendency for syneresis, and melting temperature.

The color of all the gels became darker with aging. The surface which was in contact with the enameled disc closures showed a tendency for formation of the violet-colored, complex metallic salts of anthocyan where any enamel had broken away from the metal cap. Elasticity was lost during aging and brittleness increased. The gels gradually developed the characteristics of pectic acid products.

The flavor of the gels during the first few months of storage resembled that of slightly sweetened grape juice and was rated excellent, but by the end of the first year's storage the gels made with the apple pectinate had developed a slight vinegar-like flavor. After the gels had gone through the second summer storage period, the gels made from both the citrus and the apple pectinates had developed a mixed vinegar-grape flavor. The flavor was decidedly unattractive.

The pH of the gels did not change perceptibly during storage. The citrus-pectinate gels had a pH of 2.98 and the apple-pectinate gels had a pH of 2.96.

Both sets of gels showed some syneresis. The citrus-pectinate gels showed a very slight amount; at the end of the experiment only about two grams of liquid could be drained from a glass of gel. The apple-pectinate gels showed slightly more syneresis; about five grams of liquid was obtained from a glass of gel. Syneresis was not objectionable in either case. There was no noticeable increase in syneresis after the gel was turned from the glass.

The two physical characteristics of the 30 percent soluble solids grape gels which did change considerably with storage were gel strength and melting temperature. Measurements were made at irregular intervals. For purposes of brevity only averages of determinations during a several months' period are shown in Table 1. Changes in strength and melting temperatures were of sufficient magnitude to warrant consideration in detail.

TABLE 1

Aging of Low-Solids (30%) Grape Gels Under "Store-Shelf" Conditions

Aging period between successive examinations (total 17½ months)	Citrus pectin (C.F.G.E. #B9612), 170 grade, 4.4% CH_3C, pH of gels = 2.98. Slight syneresis in all gels.		Apple pectin (E.R.R.L. #H90R, see Del. Bul. 246), 170 grade, 4.7% CH_3O, pH of gels = 2.96. Syneresis in all gels.	
	Gel strength (cm. of H_2O pressure) average	Melting temp., °F. average	Gel strength (cm. of H_2O pressure) average	Melting temp., °F. average
Start	63	140	24	145
1st, 2 months	78	143	32	152
2nd, 2 months	87	143	70	170
3rd, 2 months	87	145	95	173
4th, 2 months	75	153	78	188
5th, 2 months	96	156	110+ *	196
6th, 4 months	92	165	110+ *	205
7th, 3½ months	114	172	168	215
End of study	123	.....	177	.....

* Gel-strength tester used for measuring gels in these two periods would not read above 110 cm. These data are not plotted.

Gel Strength. The data in Table 1 and the curves of Fig. 1 show that the gel-strength of the experimental grape gels increased considerably with storage. While the rate of increase was more rapid in the case of gels made with the apple pectinate, the increase in strength seemed to parallel the loss of elasticity and increase in brittleness of both sets of gels. There was some indication, especially in the case of the gels made from the citrus pectinate, that the rate of increase in strength was greater during the summer months as might be logically expected. The character of the strength changes indicated gradual loss of methyl ester groups from the gelling agent and the formation of pectic acid with its characteristic brittle gel structure. Many are familiar with the change taking place in commercial pectin concentrate on a grocer's shelves. In a few years' time the concentrate changes to a gel due to the demethylation of the pectin and the gradual formation of pectic acid which forms a gel by itself or readily reacts with the salts of any polyvalent metals present to form a gel.

Melting Temperature. The course of deterioration in the quality of the 30 percent soluble solids grape gels is also very evident from the change in melting temperatures. The gels containing either apple or citrus pectinate could be melted below 150° F. and regelled easily at the start of the experiment. While the citrus-pectinate gels were readily melted throughout the first year, the apple-pectinate gels became quite difficult to melt and regel after six months of aging. After this period

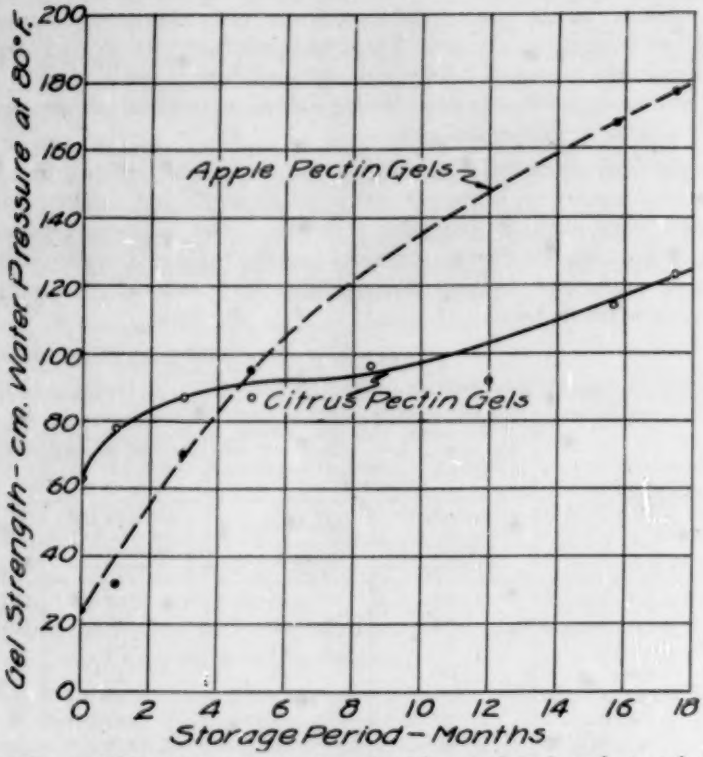

FIG. 1. Effect of storage on strength of low-methoxyl pectinate gels.

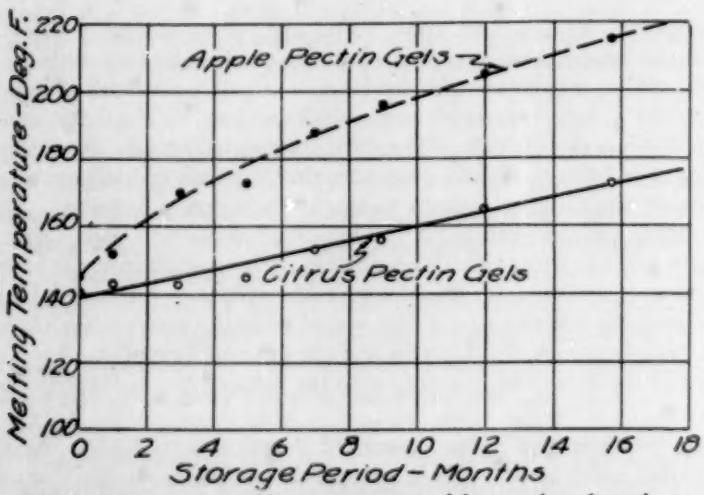

FIG. 2. Effect of storage on melting temperature of low-methoxyl pectinate gels.

of time the latter gels did not melt to a smooth syrup but tended to have granular structures present. They would regel, but the gel was weaker and much of its original elasticity was lost. According to Fig. 2, the melting temperature of the citrus-pectinate gels increased in direct proportion to the time of aging, while the melting temperature of those made with apple pectinate increased more rapidly in the early stages of storage. During the latter part of the storage period the gels exhibited such a marked similarity to pectic acid gels that it was decided to isolate the pectic material present in the gels and determine its methoxyl content.

METHOXYL CONTENT OF PECTIN IN GELS AFTER AGING

Two grape gels (approximately 350 g. of gel) from each series of gelled material were stirred with twice their volume of water. The gels containing citrus pectinate dissolved readily upon heating to boiling. The hot liquor was filtered and then precipitated by pouring into twice its volume of 95 percent ethyl alcohol. The gels containing the apple pectinate were not completely dissolved even after heating so they were poured into the alcohol without previous filtering. The precipitated material was filtered off in each case and pressed as free from liquid as possible.

The precipitates were added to water in an attempt to redisperse them. The citrus pectic material dispersed upon heating, but the apple material appeared largely as insoluble flakelets. Sufficient alcohol was again added to precipitate all pectic material. Both samples seemed to coagulate better on this second precipitation. The precipitates were filtered, pressed, washed with 95 percent ethyl alcohol and then with ether. After pressing as dry as possible they were dried at 60° C. Since 0.87 and 0.88 percent yields of alcohol-precipitable material were obtained from the grape gels for the citrus and apple pectinates, respectively, it is indicated that some extraneous or occluded matter was included in the precipitates because originally the gels contained only 0.74 percent pectinate; however, if we assume the original pectinate as 75 percent de-esterfied, reaction with the calcium would produce about 0.86 percent calcium pectinate in the gels.

The methoxyl content of the precipitates was determined by a modification of the methods of Clark *(2)* and Samsel and McHard *(4)*. The alcohol-precipitable material from the citrus pectinate gel was found to have a methoxyl content of 2.71 percent and that from the apple pectinate gel 3.01 percent. When compared with the original methoxyl values of 4.4 percent for the citrus and 4.7 percent for the apple pectinic acids and with due allowance for the change from pectinic acid to calcium pectinate, it can be assumed that the demethylation which occurred during aging was approximately the same for the citrus and the apple pectinates. Assuming 25 percent of other than pectic material in the alcoholic precipitates which were analyzed, the methoxyl values can be estimated as 3.4 percent for the citrus pectinate and 3.7 percent for the apple pectinate. The loss of methoxyl value by the pectinates during the storage of the gels can be considered to be only about one percent, but this loss in terms of its effect upon gel characteristics is excessive.

Loss of methoxyl by powdered, high-methoxyl pectinates during storage is relatively slow. It has been found to amount to a very small fraction (0.05) of one percent per year *(3)*. The intermediate and low-methoxyl pectinates appear to be less stable and lose methoxyl at a much higher rate, 0.4 percent loss per year in the powdered state and, apparently, a loss of approximately 1 percent per year in the low-solids (30 percent) gel. The loss in the case of gels will probably vary with the amount of soluble solids in the gel, being more stable the higher the soluble solids content. Temperature of storage will undoubtedly have an appreciable effect

upon the deterioration of a gel. Gels stored at 40° F. for three months showed no measurable changes in strength or melting temperatures during the storage period.

FURTHER RESEARCH REQUIRED

Major indices of deterioration with aging under "store-shelf" conditions in experimental low-solids grape gels were found to be flavor changes, increased strength with accompanying loss of elasticity, and increased melting temperatures. Progressive demethylation during storage is considered to be largely to blame for the latter two changes.

It is concluded that further research is required in order to develop more stable low-methoxyl pectinates—low-methoxyl pectinates that will resist aging more successfully when in the low-solids, gelled state. The fact that the gels made from the citrus pectinate were more stable during storage than those from the apple pectinate lend encouragement to the possibility that pectinates more resistant to aging can be developed by further study.

Acknowledgment. The authors are indebted to Dr. Elizabeth Dyer, Chemistry Department, University of Delaware, for determining the methoxyl content of the pectic materials precipitated from the gels.

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RELATIONSHIP OF MOISTURE CONTENT TO QUALITY RETENTION IN DEYHYDRATED VEGETABLES DURING STORAGE. I—TOMATO FLAKE.[1]

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The shelf-life of dehydrated vegetables, in many instances, is of surprisingly short duration. Off-flavors, color changes, retardation of rehydration, vitamin losses, "caking" of the product and other undesirable changes in quality occur at ordinary storage temperatures (65-80° F.), and temperatures of over 100° F. accelerate the same.

Clifcorn *(1)* and Kaufman *(2)* have shown that quality retention can be materially increased by hermetically sealing the dehydrated product in an inert atmosphere and by dehydrating to a low moisture content. This investigation was undertaken to determine the critical moisture level which would give dehydrated tomato flake maximum storage life at several controlled storage temperatures.

PROCEDURE

The Sardik drum drying process was used to produce samples of tomato flake containing respectively 1-1½-2½-3½ and 5 percent residual moisture. The samples were hermetically nitrogen gas-packed and stored at 40° F., room temperature (65-80° F.), and 100° F. The tomato flake was scheduled to be examined after 1-2-4-8-16 and 32 weeks' storage, with additional periods dependent upon the 32 weeks' results.

Examination of the product consisted of organoleptic tests for changes in flavor, color, aroma, rehydration and "caking," and chemical tests consisted of vitamin C and moisture tests. The atmosphere in the container was examined for carbon dioxide and oxygen content.

RESULTS AND DISCUSSION

Ascorbic Acid. Ascorbic acid was determined by the Tillmans, Hirsch, and Hirsch titration method *(3)* as modified by Bessey and King *(4)* and by Tressler and Hollinger *(5)*.

At 40° F. storage, tomato flake containing from 1 to 5 percent moisture showed no significant loss in vitamin C content for a period of 32 weeks. When stored at room temperature (65-80° F.), the tomato flake samples with 1, 1½, 2½, and 3½ percent moisture lost between 11 and 16 percent of their original vitamin C in 32 weeks' storage. The flake containing 5 percent moisture lost about 31 percent of its vitamin C. During 32 weeks' storage at 100° F., tomato flake samples with residual moisture contents of 1, 1½, 2½, 3½ and 5 percent lost respectively 30, 43, 63, 78, and 76 percent of the vitamin C originally present.

The data recorded in Table 1 and Figs. 1 and 1-A indicate that tomato flake stored at 40° F. will retain its vitamin C intact, even with a moisture content as high as 5 percent. At room temperature storage, ranging from 65-80° F., a noticeable but not serious loss in vitamin C occurred with flake having 1 to 3½ percent moisture, whereas a significant loss was encountered at the 5 percent moisture level. Since the vitamin C loss at 3½ percent moisture level was little greater than at the 1 percent moisture level, commercial practice of drying to about 3½ percent would

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 16, 1946.
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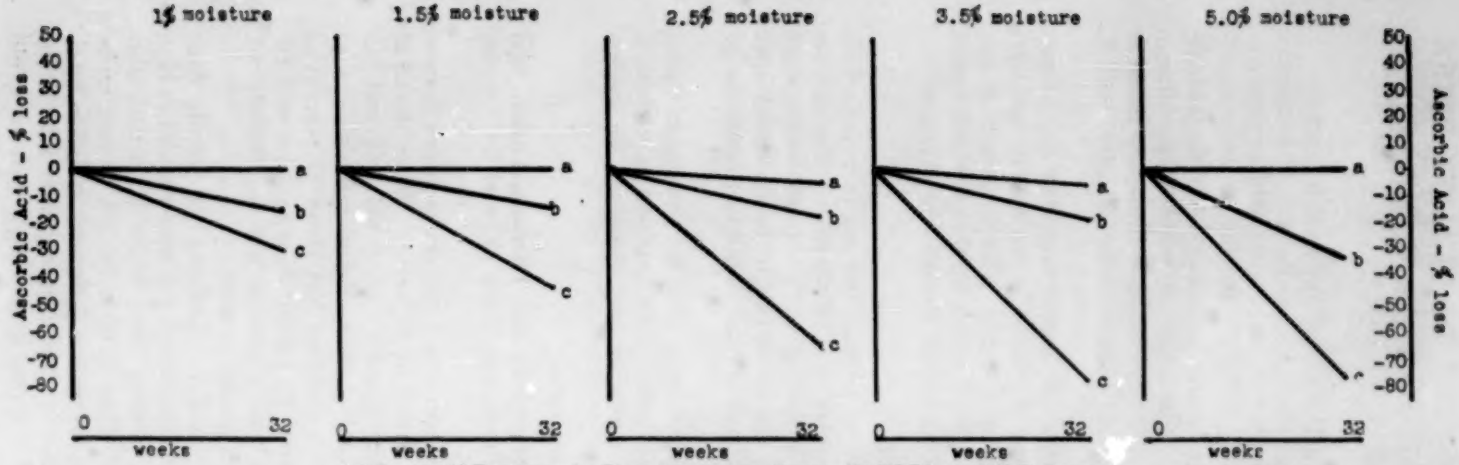
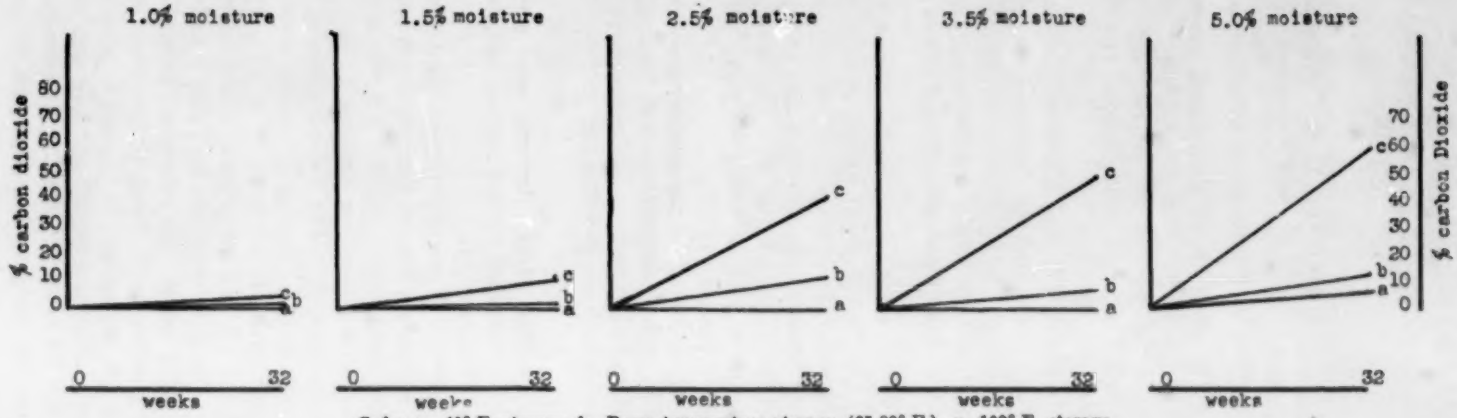


Code: a—40° F. storage. b—Room temperature storage (65-80° F.). c—100° F. storage.

FIG. 1. Percent loss vitamin C in 32 weeks.



Code: a—40° F. storage. b—Room temperature storage (65-80° F.). c—100° F. storage.

FIG. 2. Carbon dioxide in atmosphere of container after 32 weeks' storage.

seem adequate for tomato flake which would subsequently be stored at 80° F. or less. The 100° F. storage tests indicate that even with only 1 percent moisture in the tomato flake, a loss of nearly one-third of its vitamin C takes place in 32 weeks. It would seem imperative that tomato flake which was expected to retain most of its vitamin C during shipment and storage in localities having 100° F. or higher temperatures would have to be dehydrated far below 1 percent.

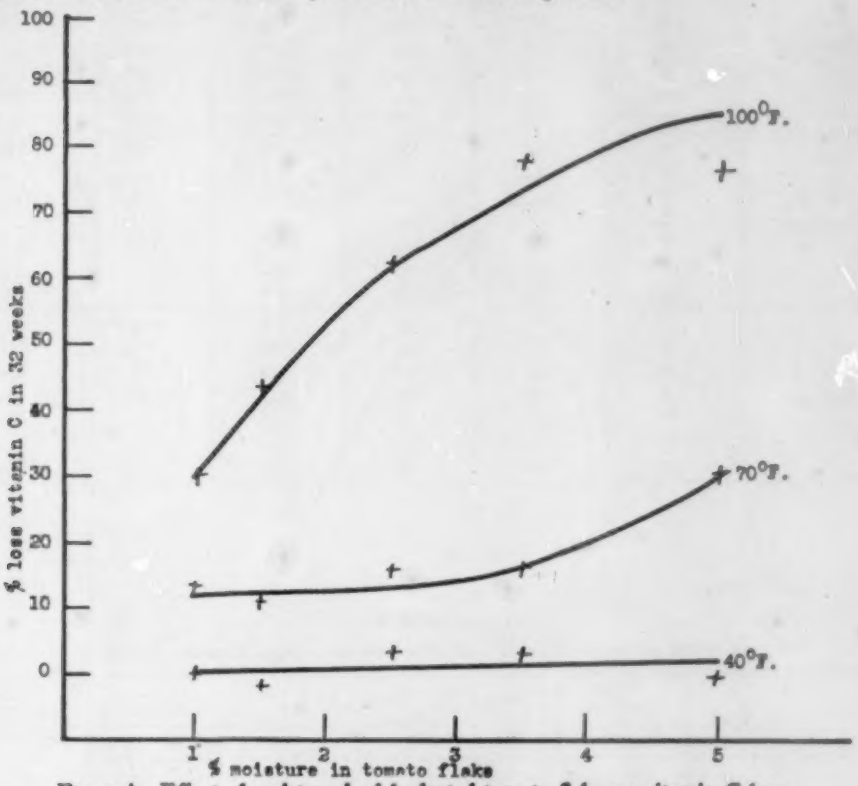


FIG. 1-A. Effect of moisture in dehydrated tomato flake on vitamin C loss.

Carbon Dioxide. The carbon dioxide was determined by the simplified Orsat method. There was little appreciable carbon dioxide production due to breakdown of the tomato flake when stored at 40° F. for 32 weeks. At room temperature storage (65-80° F.), using carbon dioxide production as a criterion of breakdown, the flake containing 1.0 percent and 1½ percent moisture remained unchanged, the flake with 2½ percent moisture showed breakdown at 32 weeks, and the flake with 3½ percent and 5.0 percent moisture, respectively, showed breakdown in 16 weeks.

When tomato flake was stored at 100° F., noticeable carbon dioxide production occurred in 32 weeks at the 1.0 percent moisture level, in 8 weeks at the 1½ percent moisture level, in 2 weeks at the 2½ percent moisture level, and in 1 week at both 3½ and 5 percent moisture levels. Based on data as indicated in Table 2 and Figs. 2 and 2-A from the carbon dioxide tests, if tomato flake is to retain lengthy storage life at 65-80° F., it should be dried well below 2½ percent moisture, and if it is to be stored at 100° F., or higher, a moisture content of less than 1 percent is necessary.

Moisture. Moisture was determined by vacuum oven at 70° F. for 6 hours (6). Moisture tests were run on all samples at all storage periods and temperatures, in

TABLE 1

Vitamin C Retention in Stored Tomato Flake

	Week	1.0% moisture	1.5% moisture	2.5% moisture	3.5% moisture	5.0% moisture
		mgm%	mgm%	mgm%	mgm%	mgm%
40° F. Storage	0	187	152	150	135	153
	1	178	161	162	137	175
	2	187	163	144	147	158
	4	195	155	175	133	.....
	8	192	.....	170	142	.....
	16	179	.....	172	111	163
	32	187	155	145	130	153
70° F. Storage	0	193	152	153	138	153
	1	.....	.....	.....	.....	.....
	2	.....	.....	.....	.....	.....
	4	.....	.....	.....	.....	.....
	8	196	124	118	130	108
	16	180	.....	.....	.....	.....
	32	167	135	128	115	105
100° F. Storage	0	180	152	153	135	144
	1	172	133	141	123	118
	2	154	126	114	117	116
	4	135	114	107	94	94
	8	142	78	73	.....	90
	16	142	.....	.....	.....	.....
	32	126	86	57	29	33

TABLE 2

Carbon Dioxide and Oxygen Analysis of Stored Tomato Flake

	Week	1.0% moisture		1.5% moisture		2.5% moisture		3.5% moisture		5.0% moisture	
		CO_2%	O_2%	CO_2%	O_2%	CO_2%	O_2%	CO_2%	O_2%	CO_2%	O_2%
40° F. Storage	0	0.0	1.6	0.0	0.0	0.3	0.5	0.0	3.7	0.0	0.0
	1	0.4	1.8	0.0	1.6	0.5	3.2	3.0	3.7	0.0	3.7
	2	0.1	1.6	0.2	2.4	0.0	3.9	0.0	3.3	0.6	2.6
	4	0.0	2.4	0.3	2.3	0.0	2.9	0.2	4.6	0.0	2.9
	8	0.1	2.0	0.0	5.3	0.0	4.0	0.3	7.2	0.0	4.4
	16	0.1	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	32	0.0	0.0	0.0	12.0	0.0	0.0	0.0	11.0	1.0	2.5
70° F. Storage	0	0.0	0.6	0.3	0.5	0.3	3.0	0.8	3.2	0.8	2.8
	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	8	0.0	5.6	0.0	1.8	0.0	3.6	1.2	5.2	1.1	3.3
	16	0.0	0.5	0.4	2.0	1.2	2.0	7.9	2.2	6.5	2.6
	32	0.8	0.2	0.0	9.0	9.4	6.6	8.0	4.0	11.8	1.4
100° F. Storage	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1	0.0	1.5	0.0	4.3	0.0	4.4	3.2	3.8	4.1	4.1
	2	0.1	1.3	0.8	2.8	5.6	1.9	13.5	1.6	14.5	1.1
	4	0.0	1.8	0.0	3.0	6.7	2.0	18.4	1.4	29.4	0.2
	8	0.2	2.6	4.3	1.8	6.8	0.1	44.0	0.0	48.0	1.0
	16	1.3	14.0	7.4	2.8	45.0	.....	50.0	0.0	57.5	0.0
	32	4.2	2.4	12.0	0.0	42.0	0.0	48.0	0.0	58.0	0.0

order to determine any increases due to breakdown of the product. At 40° F. and room temperature (65-80° F.), there was no significant increase in the moisture in the tomato flake samples under study. The samples stored at 100° F. showed no great increase in moisture content at the 1.0 percent and at the 1½ percent levels. The samples dried to about 2½, 3½, and 5 percent moisture, after 32 weeks' storage contained respectively 4.7, 5.7, and 7.8 percent moisture.

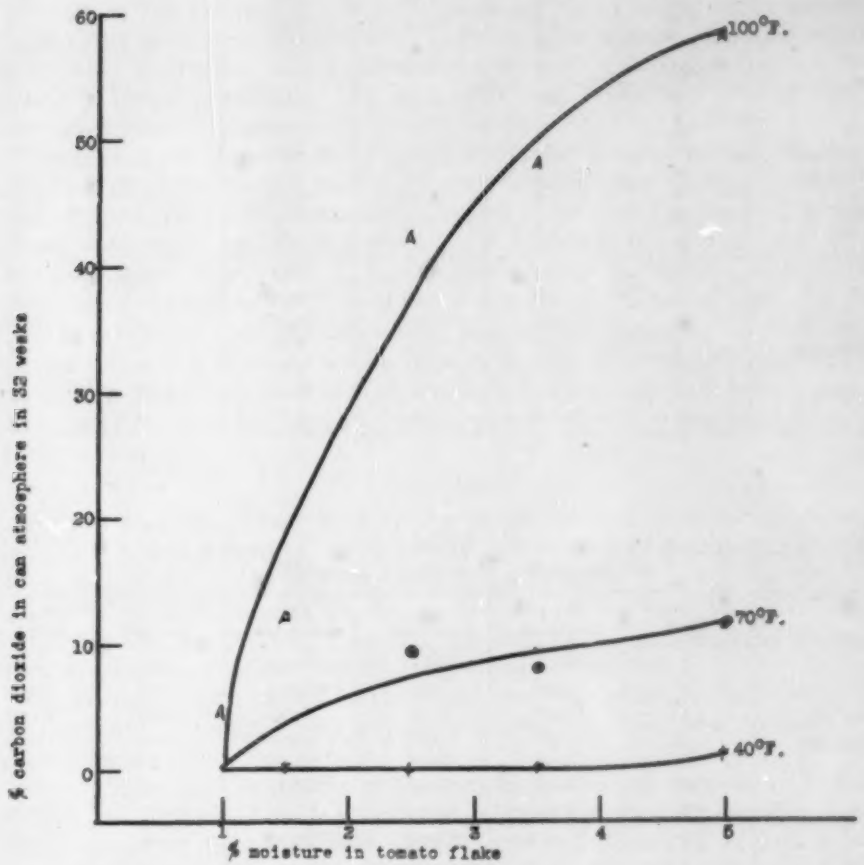


FIG. 2-A. Effect of moisture in dehydrated tomato flake on evolution of carbon dioxide.

The results from the moisture data as shown in Table 3 indicate that tomato flake containing from 1 to 5 percent moisture content can be stored at 40° F. or 65-80° F. for 32 weeks with little loss in quality. When stored at 100° F., the critical moisture level seems to be below 2½ percent, probably quite near to 1½ percent.

Flavor, Color, Rehydration, and "Caking." The 40° F. storage results for 32 weeks showed no detrimental changes in flavor, color, and rehydration of tomato flake containing from 1 to 5 percent moisture. The sample with 5 percent moisture content had "caked" slightly after 2 weeks' storage, and had formed a hard "cake" in the container in 16 weeks.

The room temperature storage (65-80° F.) showed no important palatability decrease or color change after 32 weeks at all moisture levels. The 3½ percent

TABLE 3

Percent Moisture in Stored Tomato Flake

	Week	1.0% moisture	1.5% moisture	2.5% moisture	3.5% moisture	5.0% moisture
40° F. Storage	0	.93	1.45	2.30	3.61	4.79
	1	.69	1.63	2.99	3.86	4.46
	2	1.01	1.56	2.51	3.76	4.82
	4	1.09	1.59	2.58	3.65	4.83
	8	.96	1.27	2.57	3.75	4.95
	16	.88	1.46	2.11	3.83	4.87
	32	1.08	1.53	2.46	3.72	4.64
70° F. Storage	0	.95	1.48	2.64	3.58	4.73
	1	.....	.....	.....	.....	.....
	2	.....	.....	.....	.....	.....
	4	.....	.....	.....	.....	.....
	8	.85	1.59	2.40	3.67	4.93
	16	.92	1.63	2.61	3.55	4.73
	32	.97	.....	.....	3.50	4.85
100° F. Storage	0	.94	1.53	2.73	3.46	4.80
	1	.98	1.48	2.40	3.51	4.66
	2	.96	1.60	2.59	3.93	5.08
	4	1.07	1.34	2.33	3.72	5.34
	8	1.06	1.83	3.79	5.18	7.20
	16	.98	1.65	6.06	5.18	6.83
	32	1.09	1.81	4.75	5.70	7.82

TABLE 4

Palatability of Stored Tomato Flake

	Week	1.0% moisture	1.5% moisture	2.5% moisture	3.5% moisture	5.0% moisture
40° F. Storage	0	Good	Good	Good	Good	Good
	1	Good	Good	Good	Good	Good
	2	Good	Good	Good	Good	Good
	4	Good	Good	Good	Good	Good
	8	Good	Good	Good	Good	Good
	16	Good	Good	Good	Good	Good
	32	Good	Good	Fair	Fair	Good
70° F. Storage	0	Good	Good	Good	Good	Good
	1	.....	.....	.....	.....	.....
	2	.....	.....	.....	.....	.....
	4	.....	.....	.....	.....	.....
	8	Good	Good	Good	Good	Good
	16	Good	Good	Good	Good	Good
	32	Good	Good	Fair	Fair	Good
100° F. Storage	0	Good	Good	Good	Good	Good
	1	Good	Good	Good	Good	Good
	2	Good	Good	Good	Good	Good
	4	Fair	Fair	Poor	Poor	Poor
	8	Good	Good-fair	Fair	Poor	Poor
	16	Fair	Fair	Poor	Poor	Poor
	32	Good	Fair	Poor	Poor	Poor

moisture sample rehydrated poorly at 32 weeks and had "caked" badly in the container. The sample containing 5 percent moisture had formed a hard "cake" in 8 weeks.

At the 100° F. storage temperature, the sample with 1 percent moisture showed little quality loss, as judged by palatability, darkening in color, "caking," and rehydration. The 1½ percent moisture sample had definitely changed from good to fair at the end of 16 weeks, with no appreciable change in color, "caking," or rehydration. The 2½ percent and 3½ percent samples were "caked" hard after 2 weeks' storage, were poor in palatability after 4 weeks, were dark in color and rehydrated poorly after 16 weeks. The 5 percent sample was "caked" hard after 1 week's storage, had poor palatability, and dark color in 4 weeks, and showed very poor rehydration after 16 weeks.

The information from Tables 4 and 5 shows that tomato flake stored at 40° F. should be dehydrated to less than 5 percent moisture, since "caking," a very undesirable characteristic to the consumer, occurred in 32 weeks' storage. Flake stored at room temperature (65-80° F.) should be dried below 3½ percent residual moisture, since again undesirable "caking" occurred after 32 weeks' storage. When tomato flake is stored at 100° F. or higher, a maximum moisture content of 1 percent should be permitted, and preferably nearer ½ percent is advisable. With 1½ percent moisture in tomato flake, 32 weeks' storage at 100° F. definitely reduces quality from good to fair. Any flake with moisture over 1½ percent will have a very short and impractical shelf-life, indeed, when stored or shipped at temperatures of 100° F. or more.

SUMMARY

Tomato flake was drum dried by the Sardik method, to moisture levels of 1, 1½, 2½, 3½ and 5 percent. The samples were nitrogen gas-packed in tin containers, and stored at 40° F., room temperature (65-80° F.), and 100° F.

After 1, 2, 4, 8, 16 and 32 weeks' storage, the samples were examined for palatability, vitamin C content, carbon dioxide production and moisture increase due to breakdown, "caking," color changes and rehydration.

All samples of flake stored for 32 weeks at 40° F. retained their quality unimpaired except the sample with 5 percent moisture which was "caked" after 2 weeks' storage.

At 70° F. storage for 32 weeks, the samples containing 1 percent, 1½ percent, and 2½ percent moisture, respectively, showed satisfactory quality retention, although about 10 percent of their ascorbic acid had been lost. The sample with 2½ percent moisture showed carbon dioxide production after 32 weeks' storage, indicating that there was greater breakdown at this moisture level than at the lesser levels. The tomato flake samples with 3½ percent and 5 percent moisture after 32 weeks' storage were "caked" hard, showed carbon dioxide production, and loss of 16-30 percent of their ascorbic acid.

At 100° F. storage the flake with 1 percent moisture content had retained its quality well for 32 weeks, except for loss of almost one-third of its vitamin C. The 1½ percent moisture flake showed a decrease in palatability from a rating of "good" to one of "fair" in 32 weeks. The samples with 2½, 3½ and 5 percent residual moisture were poor in quality within 4 weeks.

CONCLUSION

A moisture content in dehydrated tomato flake not exceeding 3½ percent is necessary for prolonged storage life at 40° F., while at room temperature storage (65-80° F.) the moisture should be between 1½-2½ percent, preferably the former.

TABLE 5

Color, Caking, and Rehydration of Stored Tomato Flake

	Week	1.0% moisture			1.5% moisture			2.5% moisture			3.5% moisture			5.0% moisture		
		Co.	Ca.	Rehy.	Co.	Ca.	Rehy.	Co.	Ca.	Rehy.	Co.	Ca.	Rehy.	Co.	Ca.	Rehy.
40°	0	Nml.	None	Good	Nml.	None	V. gd.	Nml.	None	V. gd.	Nml.	None	V. gd.	Nml.	None	V. gd.
	1	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good
	2	Nml.	None	Good	Nml.	None	Poor	Nml.	None	Good	Nml.	None	Good	Nml.	Sl. hd.	Good
	4	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	Sl. hd.	Good
	8	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	Sl. hd.	Good
	16	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	Hard	Good
	32	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	Hard	Good
70°	0	Nml.	None	Good	Nml.	None	V. gd.	Nml.	None	Good	Nml.	Sl. hd.	V. gd.	Nml.	None	V. gd.
	1	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good
	2	Nml.	.....	.....	Nml.	.....	.....	Nml.	.....	.....	Nml.	.....	.....	Nml.	.....	.....
	4	Nml.	.....	.....	Nml.	.....	.....	Nml.	.....	.....	Nml.	.....	.....	Nml.	.....	.....
	8	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	Hard	Good
	16	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	Hard	Good
	32	Nml.	None	Good	Nml.	None	Good	Nml.	None	Fair	Nml.	Hard	Poor	Nml.	Hard	Good
100°	0	Nml.	None	Good	Nml.	None	V. gd.	Nml.	None	V. gd.	Nml.	None	V. gd.	Nml.	None	V. gd.
	1	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	None	Good	Nml.	V. hd.	Good
	2	Nml.	None	Good	Nml.	None	Fair	Nml.	Hard	Good	Nml.	V. hd.	Good	Nml.	V. hd.	Good
	4	Nml.	None	Good	Nml.	None	Good	Nml.	Hard	Good	Nml.	V. hd.	Good	Dark	V. hd.	Good
	8	Nml.	None	Good	Nml.	None	Fair	Sl. dk.	V. hd.	Fair	Dark	V. hd.	Fair	V. dk.	V. hd.	Fair
	16	Nml.	None	Fair	Nml.	None	Good	Dark	V. hd.	Poor	V. dk.	V. hd.	Poor	V. dk.	V. hd.	V. poor
	32	Sl. dk.	None	Good	Sl. dk.	None	Good	Dark	V. hd.	Fair	V. dk.	V. hd.	Poor	V. dk.	V. hd.	V. poor

Code:

Co.—Color
Ca.—Caking
Rehy.—Rehydration
Nml.—Normal
V. gd.—Very good
Sl. hd.—Slightly hard
Sl. dk.—Slightly dark

Tomato flake stored at 100° F. or higher will have short "shelf-life," unless its moisture content is approximately 1 percent at maximum.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of Mrs. Mae (Jenkin) Donovan in carrying out the palatability tests.

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THE EFFECT OF THE NATURE OF THE FOOD EATEN UPON THE DESIRE FOR FOOD[1]

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INTRODUCTION

Advances in nutrition have been phenomenal. We know most of the essential minerals, fatty acids, amino acids and vitamins. Progress has been made in characterizing nutritional disorders resulting from the absence in the diet of many of these essential nutrients. Analytical procedures for the measurement of these essential nutrients are receiving a great deal of study, and methods are being rapidly perfected for the assay of new nutritional factors.

Too little attention has been paid by nutrition investigators to acceptability of foods and they may have overlooked an important phase of nutritional studies. Some recent observations on food acceptability with the human are:

1. Some foods such as bread can be eaten for unlimited periods of time in almost unlimited amounts.

2. Some foods such as cheese and eggs can be eaten for unlimited periods of time if consumed in limited amounts.

3. Some foods can be eaten for limited periods of time if fed only in limited amounts.

The reasons for such differences in acceptability of foods are not too clearly understood. The psychological reactions of human beings to food have been studied very extensively. The importance of taste, texture, odor, color, temperature and habit has been appreciated and studied. This phase of food acceptance has been discussed by Dr. Dove at this meeting.

Scant attention has been paid to the possible physiological effects of food and their possible role in acceptability. It is possible that a better understanding of the physiological effects of food will help explain psychological reactions to food and throw more light on the overall problem of food acceptance. The recent literature has been summarized by Richter *(1)*.

THE ROLE OF NUTRITIONAL ADEQUACY ON THE ACCEPTABILITY OF FOODS

Extensive observations in laboratory studies with rats and chicks seem to indicate that acceptability of food by these animals is determined almost solely by the nutritional adequacy of the diet. Little of the psychological aspects of acceptabiilty seem to play any appreciable role with these animals. Foods will be rejected if they are nutritionally inadequate. When the missing nutrient or nutrients are returned to the diet, it becomes at once acceptable and is greedily eaten.

Human beings are fundamentally no different. They may eat a nutritionally inadequate diet so long as they can draw upon the body stores for the missing nutrients. This may be a relatively long period of time. When the body stores are exhausted of the required essential nutrients, the food becomes unacceptable due to loss of appetite. The doctor corrects the patient's nutrition, appetite is restored and the food again becomes acceptable.

The citizen has a free choice in selecting his diet. He may choose a diet that has a high nutritional value or one that is nutritionally inadequate. His choice is not made easy by the advertising promoting the sale of foods. It is remarkable, under

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 16, 1946.

these conditions, how well the average citizen does choose his diet, since dietary surveys indicate there are few recognizable nutritional deficiencies in the population. Somehow or other, the average citizen chooses a fairly adequate diet. Perhaps the choice is fortuitous or it may be that the human being can still react to food in such a way so that he can distinguish between foods which are "good" for him and those which are not. The larger the choice of foods of high quality or "protective foods," the more likely the average citizen will choose a good diet. As the "protective foods," which provide proteins of high quality, minerals and vitamins, become scarcer, the more difficult will it be for people to choose adequate diets. Should the diet of people become inadequate, foods once palatable and acceptable will no longer be as acceptable. The merchandisers of nutritionally inadequate foods are dependent upon the merchandisers of "protective foods" for the continued acceptability of their products. A sharp decline in the availability of "protective foods" could well alter the acceptability of many nutritionally inadequate foods now enjoying high acceptability.

We are entering a period of food shortage. The period may be temporary, or in the event of a short crop it may be prolonged. Animal foods such as dairy products, meat, fish and poultry products, which are our most important "protective foods," will become scarce. Under such conditions, the overall food intake could very well result in a nutritionally inadequate diet, which could have far-reaching effects on the acceptability of foods of low nutritional value.

Some light is shed on the ability of the human to choose food correctly by the experience of some American soldiers *(2)* in a German prison camp. The American soldiers were slowly starving to death and they knew it. A situation was created where there was a direct relation between food intake and survival without the complicating social influences. Survival for these American soldiers in the German prison camp was made possible by the Red Cross packages which occasionally reached them. The Red Cross packages contained such items as powdered milk, canned meat, cheese and candy. These items were traded among the men and a point system was set up to evaluate the different items which reflected the demand for them. Milk had the highest point value, 150 points; meat followed with 130 points, and the others followed with a smaller number of points. Under these conditions, the soldiers rated the food in accordance with their nutritional adequacy. The choice may have been fortuitous or it may have been indicative that under these conditions the soldiers reacted in such a way to the different food items as to be able to distinguish between them in accordance with their nutritional values.

It is not an extravagant assumption that human beings can and do distinguish between adequate and inadequate foods and so choose their diets that they are nutritionally adequate. The survival of the human race depended upon the choice of a nutritionally adequate diet. To contend that the human race accidentally chose a nutritionally adequate diet would be putting its survival upon tenuous grounds.

THE PHYSIOLOGICAL BEHAVIOR OF FOOD IN THE GASTROINTESTINAL TRACT AND ITS EFFECT ON THE ACCEPTABILITY OF FOOD

Little is known about the effect of food as it passes through the gastrointestinal tract during digestion upon the acceptability of the food. An attempt will be made to outline an experimental approach to this problem.

THE EFFECT OF FOOD ON THE FLOW OF THE DIGESTIVE JUICES

The effect of the food on the flow of digestive juices could well be a factor in the acceptability of foods. Spices, as an example, increase the amount and acidity of

gastric juice. This may be in part the reason why spices increase the acceptability of foods. Spice-like compounds or flavors naturally present in foods may also have some physiological action. Changes in acceptability of foods by prolonged cooking, canning or dehydration may in part be the result of chemical or physical alteration of some flavor component whose physiological action has been changed or lost during processing.

THE EFFECT OF FOOD ON THE COMPOSITION OF THE CIRCULATING BODY FLUIDS

Upon digestion of foods, the digestion products such as amino acids, sugars and fats are absorbed by the blood thus changing the composition of the circulatory fluids. These fluids bathe the appetite center or centers and may exert some influence upon them, stimulating or depressing hunger or appetite. A high carbohydrate meal causes a high blood sugar which stimulates the secretion of insulin, which in turn causes a sharp drop in blood sugar, thus causing hunger. A high protein meal on the other hand delays the onset of hunger and causes a sense of well being for possibly two reasons:

1. The blood sugar level is maintained for a longer period of time.
2. The absorbed amino acids increase the concentration of the amino acids in the blood. This may be one cause for a decrease in appetite since injection of protein hydrolyzates causes anorexia.

THE RATE OF MOVEMENT OF FOOD THROUGH THE GASTROINTESTINAL TRACT

Some foods move through the gastrointestinal tract faster than others, and the rate of movement of the food could well reflect upon its acceptability. The gastric emptying time associated with the food could well be of special importance since there could be no desire for food when the stomach is full of food. Too little is known about the speed with which different foods move through the gastrointestinal tract.

THE ROLE OF BULK UPON ACCEPTABILITY OF FOOD

Bulk has long been considered as playing an important role in constipation. Factors influencing elimination may play important roles in acceptability. The role of microorganisms in laxation has been appreciated for a long time. They attack bulk differently, depending on the type of bulk and perhaps also on the microbiological flora in the intestinal tract *(3)*. The crude fibre of wheat bran is decomposed to a limited extent, and is laxative. The crude fibre of cabbage is decomposed to considerable extent and is laxative. The crude fibre of lettuce and celery is also decomposed to a large extent but is not laxative *(4)*.

The intestinal bacteria may play their role on laxation in the following ways:

1. Removal of bulk from the gastrointestinal tract.
2. Synthesis of compounds which have a laxative action.
3. Synthesis of nutrients which may make the ration more adequate nutritionally.
4. Formation of moderate amounts of gas which if distributed through the intestinal contents as fine bubbles, will increase the bulk and stimulate peristalsis and elimination.
5. Production of too much gas causes excess flatus and is undesirable.

EFFECT OF DELETERIOUS COMPONENTS IN FOODS ON ACCEPTABILITY

Deleterious components of one kind or another are widely distributed in foods. An excellent example of a food containing deleterious components is the soy bean.

Some of the better known are lipoxidase, a goiterogenic factor and an antitrypsin. The antitrypsin prevents proper utilization of the soy bean proteins. Autoclaving the soy beans destroys the antitrypsin and perhaps other deleterious components and greatly increases the acceptability of the soy beans.

Animals will often limit the intake of food components which contain a deleterious compound to protect themselves against intoxication. When gossypol is included in a ration that is highly acceptable to a rat, the ration becomes unacceptable. The reaction of animals to foods containing toxic compounds varies with the compound and with the animal. Often animals will eat sufficient food containing a toxic compound to cause intoxication. The animal has to choose between death from starvation or the consequences of the ingestion of a toxic compound. That is a difficult choice to make. Perhaps deleterious components in foods play a greater role in determining their acceptability than has hitherto been supposed.

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SUBJECTIVE AND OBJECTIVE TESTS AS FOOD RESEARCH TOOLS WITH SPECIAL REFERENCE TO POULTRY MEAT[1]

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Smith *(4)* presented an excellent discussion of the various methods used for objective measurement of quality in foods. No one will deny the obvious advantages such tests possess with respect to reproductibility and in the ease of applicability to the needs of the control laboratory. However, it should be recognized that they have some important limitations. In the present discussion it is hoped to point out some of these as well as to explore some of the many problems involved in developing criteria for measuring the organoleptic qualities of foods.

INTRODUCTION

Foods have many quality characteristics. These may be conveniently classified into the following categories:

1. Nutritive composition
2. Acceptability (odor, flavor, texture, color, body, juiciness, etc.)
3. Health hazards (freedom from chemical and bacteriological toxins and pathogenic organisms)
4. Sanitary quality (freedom from foreign particles and filth and other evidences of unsanitary environment)
5. Utility (convenience of use, functional properties, etc.)
6. Keeping quality (deterioration in 1, 2 and 5)

It is obvious that the measurement of nutritive value, health hazards, sanitary quality and under some circumstances utility can be made by objective means. However, acceptability of foods is of necessity, based on subjective reactions. Whether or not objective tests can adequately replace them is dependent on finding physical and (or) chemical means suitable for measuring the various factors which control food acceptance. In other words objective tests for organoleptic qualities must measure those characteristics which are correlated to acceptability.

There are many examples in the literature of tests for measuring such varied acceptance characteristics of foods as texture, color, tenderness, body, juiciness, etc. There are objective tests for some food flavors; *e.g.*, tests for diacetyl and, of course, sugar and salt. Presumably as our knowledge of the chemical and physical properties of food increases we should be able to devise tests which will measure almost any characteristic of food which pertains to organoleptic acceptability. It should be emphasized however that the proper interpretation of these tests, acceptance-wise, is dependent on an established relationship between the objective test values and acceptability. Many of the commonly employed objective tests fall far short of adequately measuring organoleptic quality. The "body" of most liquid foods is not simple manifestations of viscosity measurements.

Subjective tests measure, in the expression of opinion, the qualities of food as they make their impression individually and collectively on the sensory organs. They are subjective because the individual is required to go through a mental process in giving his opinion as to qualitative and quantitative value of the characteristic or characteristics under study. Since a large part of the acceptability of food is related to sensory perception the tests are inherently associated with acceptability. It is recognized, of course, that other psychological (such as taboo, fear, habit) and physiological factors may affect acceptability.

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 16, 1946.

There is much confusion among food research workers regarding the use of subjective tests. Some regard all subjective tests as giving mere expressions of preference. This is not necessarily the case. Subjective tests may be conveniently classified into two categories: (a) preference (acceptance) tests, and (b) difference (psychometric) tests.

In preference testing the degree of acceptance is obtained. When conducted with large enough numbers of people within a population this permits the determination of consumer acceptance of a product. When done with foods in general this permits the determination of population appetite levels.

The psychometric tests are for determining quantitative differences, *i.e.*, rating or scoring food quality factors. Thus they can be used to evaluate quality changes in a given food during storage life and processing treatments. In addition they can be used to evaluate quality differences among breeds, varieties or formulas. This makes these tests valuable research and development tools.

Whereas subjective tests are difficult to control, they present possibilities, from a sensitivity standpoint that are often startling. It is pertinent to note the following sensitivities which have been recorded in the literature:

ODOR

Chlorophenol	0.4×10^{-6} mg/1
Ionone	0.1×10^{-6} to 0.5×10^{-7} mg/1
Artificial musk	0.4×10^{-7} to 0.5×10^{-6} mg/1
Vanillin	0.5×10^{-6} to 0.2×10^{-6} mg/1

TASTE

Sugar (cane)	7 milligrams
Salt	1.5 milligrams
Tartaric acid	0.2 milligram
Caffeine	0.04 milligram
Quinine	0.016 milligram
Saccharine	0.012 milligram

Particle size—1/2500 to 1/25000 of an inch
Thickness of skins—1/1000 to 1/2000 of an inch

BODY OF SOLUTIONS

Sodium chloride	0.93 molar
Manganese sulphate	0.42 molar
Glycerine	0.65 molar
Cane sugar	0.18 molar

In the authors' laboratories, in addition to evaluating the quality of finished products, subjective tests have been found to be very useful in the study and standardizing of food preparation technics. A specific example of this is in the beating of egg white for angel cake making.

No satisfactory objective test has been found that will permit measurement during the continuous beating of the egg white. If the beating process is stopped to take intermittent objective tests the foam retrogrades during these intervals of time. However, with practice an endpoint of great accuracy for beating of the egg whites can be developed from observing the appearance (the size of the bubbles, the disappearance of translucency and development of opacity, and the increasing stiffness of the whites) of the foam. A specific gravity determination at the endpoint gives a permanent record and checks the accuracy of the operator. Any good, conscientious observer can acquire great proficiency in this type of test. The accuracy attained by some observers is excellent.

In actual practice the authors have found it desirable to employ both subjective and objective tests in connection with research on the functional and organoleptic

properties of food products. During the development of an objective test it is particularly appropriate to run parallel organoleptic tests in order to test the degree of correlation between them. After having established a good objective test, simultaneous organoleptic tests will often prove fruitful in explaining unexpected results in the objective or subjective tests.

SELECTION OF A PANEL

Usually emphasis is placed upon each member of the test panel having a very high sensitivity to the given factors under investigation. In a research laboratory (either industrial or collegiate) there is often insufficient time to select such judges from the population at hand; nor is it always necessary. One is usually limited for judges to members of the population who can conveniently make ratings at various times during the day and week. A testing panel should be considered as a tool. As such it can be compared to chemical and physical methods. Certain methods and tools may be used to show gross differences, but as more refined and precise measurements are required, then more sensitive methods and tools are used.

Differences which can be detected by the average consumer can easily be detected by members of a panel who have average sensitivity to the qualities being considered. When small differences in the food product are to be detected (differences which few consumers would notice, yet which might represent, for example, real trends in shelf life) then the members of the panel should be selected with greater care.

It is seldom the case that a judge is equally proficient in testing all qualities or all flavors in foods. For example, one member of a panel may detect a certain flavor in much smaller concentration than a second member, but for another flavor a second judge may be more efficient. The same holds for texture, tenderness, and other qualities.

The members of a panel should be healthy and seldom have colds. They should be good observers, conscientious and concentrate on the job. A careless person, even if endowed with high sensitivity to food qualities, will not make a consistent judge.

The performance of an average panel can be improved by: (1) training, (2) by giving descriptive terms with each numerical rating which helps the judge to establish and maintain his standards, (3) by preventing interruptions and distraction during the scoring period, (4) to present when possible a control of good or known quality along with the other products to be scored, and (5) to provide for a sufficient number of replications.

It should be emphasized that statistical evaluation of the data obtained by a test panel is very important. The appropriate analysis, *i.e.*, variance, covariance, correlation, etc., will vary with the statistical design of the particular experiment. The scores of each judge may be analyzed separately and the deviations from his and the panels' means determined. This analysis may show that one judge's scores are so lacking in consistency that they should not be included with the scores of the remainder of the panel. Analysis of variance of the data for the various treatments should be made. Interactions can be used to indicate the predominating effect of varying treatments in causing differences or deterioration. If simultaneous subjective and objective tests have been made on a given quality, correlation coefficients will indicate the degree of relationship between them.

POST MORTEM CHANGES IN POULTRY MEAT

Selection of Subjective Tests. In the studies to be reported here only the acceptance qualities of poultry meat are considered. The main object of the investigations was to study the post-mortem changes occurring in poultry meat and then to

determine the optimum conditions for handling the product during processing, storage and cooking.

The following factors have been found important:

1. Examination prior to cooking
   a. Appearance
      1. Condition of skin
      2. Moistness
      3. Defects (bruises, blood clots, discoloration, gall stains, etc.)
   b. Aroma
      1. General
      2. Hip joint
      3. Kidney area
      4. Giblets
   c. Physical condition (firmness of carcass)
2. Examination during cooking
   a. Rate of heat penetration
   b. Cooking time
   c. Cooking losses
      1. Drippings
      2. Volatile
   d. Aroma
3. Examination after cooking
   a. General
      1. Aroma
         a. Kidney area
         b. Hip joint
         c. Drippings
         d. Giblet cooking liquid
      2. Degree of browning
   b. Panel examination—breast, thigh and giblets
      1. Aroma
      2. Flavor
      3. Tenderness
      4. Juiciness

The subjective tests are more accurate if surrounded with various controls. Among those which have been particularly helpful in reducing replication error are:

1. Individual variation is minimized by selected birds of uniform age, sex and breed for each test. Large differences have been noted in the behavior of different types of poultry, especially in regard to the rate of tendering and in cooking.

2. A minimum number of variables have been studied at any one time; preferably not more than 2 or 3. This restriction is sometimes modified, particularly in the exploratory stages of a study. In these instances it is possible to obtain more general information (though less accurate) permitting a better orientation before proceeding along specific lines. Later tests are set up on a basis of a statistical design worked out with members of the statistical laboratory.

3. The person preparing, cooking, and serving the poultry must have preliminary training in scoring (the appearance, aroma, and physical conditions prior to cooking, the aroma during cooking, and the general characteristics of the poultry after cooking) before starting a research problem. This improves accuracy in scoring; in addition preparation technics (such as placing a thermometer in muscles) as well as serving technics (serving each scorer the same anatomical part) are better standardized.

4. The panel also undergoes a training period in order to gain experience with the product and in rating differences in its various organoleptic properties which

arise as a result of treatment. The panel scores the poultry cooked in the preliminary tests. Each judge scores the samples independently.

5. The scoring system is based on 10 points, with a range of 0-10. A score of 10 represents that specimen considered to be entirely acceptable. Quantitative deviations from this are estimated by the judges to the nearest whole number (down to zero).

6. "Blind" controls are frequently used. For example a control broiler in a bird of that class properly slaughtered, dressed and then held 18-24 hours at 30-35° F. (for maximum tenderness) prior to cooking.

Selection of Objective Tests. The possibilities of objective tests to complement the subjective ones have been given considerable attention. This has led to the use of the following technics and devices:

FIG. 1. The Iowa State College motor-operated shearing apparatus with a Warner-Bratzler blade. Used in comparing tenderness of poultry muscles after varying treatments.

a. The shearing apparatus with a Warner-Bratzler blade *(3)*. This device is used for measuring tenderness. It is shown in Fig. 1. When used under carefully controlled conditions it accurately measures the tenderness of specific muscles. An example of the relationship between subjective scores for tenderness and the values obtained from the shearing apparatus is shown in Fig. 2.

b. Press fluid determination. This apparatus measures the amount of fluid which can be expressed from a sample of meat by the application of a uniform pressure for a given length of time. (Fig. 3.) It was originally proposed for use as the objective measurement of juiciness *(1)*. It has not been possible to obtain a consistent relationship between the pressometer values and scores for juiciness.

c. pH. The pH of the muscle changes with aging of poultry. In some tests it has been helpful in explaining unexpected variations in scores.

d. Histological sections. These tests have been very useful in making possible a better understanding of the organoleptic changes brought about by rigor mortis, cooler storage, freezing, storage and cooking. The application of these technics

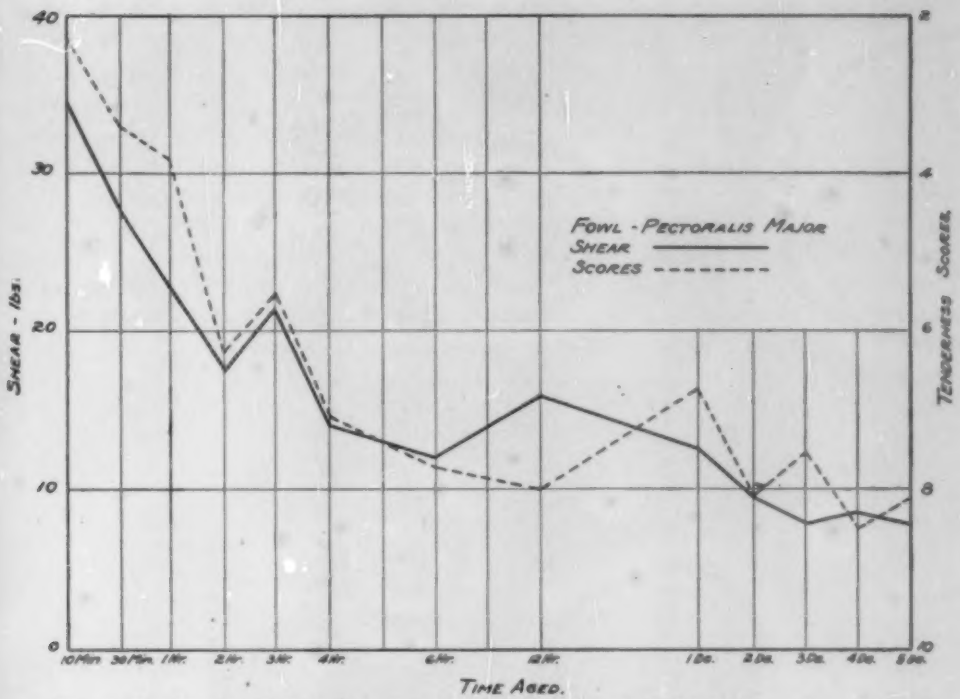

FIG. 2. Tenderness of the pectoralis major muscle of fowl (5 birds for each period) after aging for varying periods of time, as determined by shearing and by a test panel.

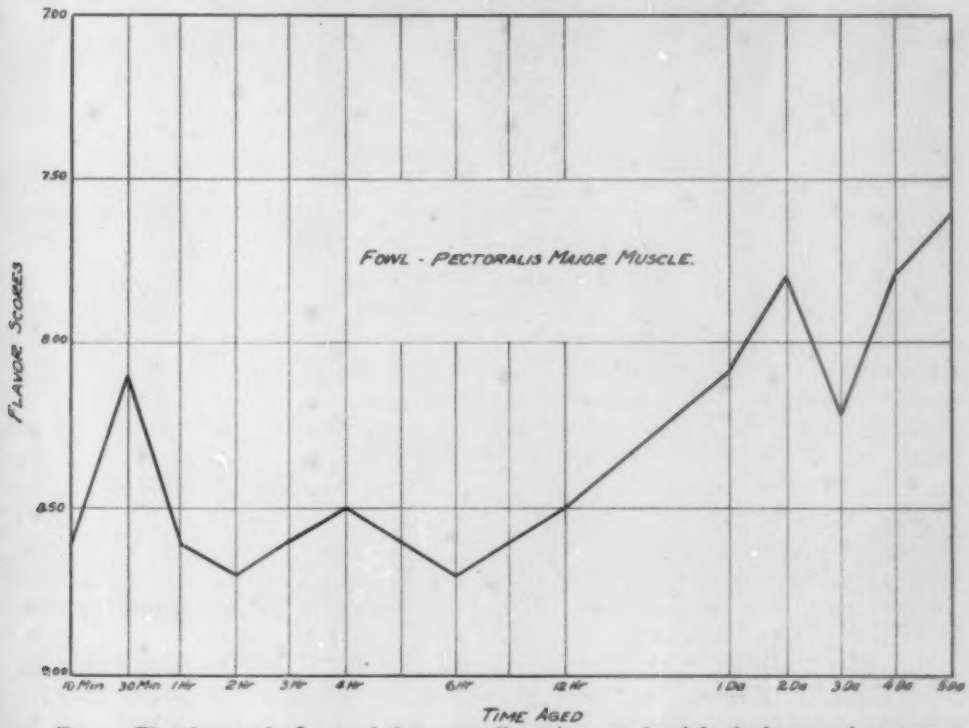

FIG. 4. The changes in flavor of the pectoralis major muscle of fowl after varying storage periods at 30-40° F. The flavor of the thigh muscles deteriorated more rapidly than the breast. The fowl held short periods, 10 and 30 minutes, were not chilled before cooking.

requires considerable experience and skill. Therefore, it seems improbable that they will be used for routine examination of meats.

e. Figs. 2 and 4 show typical organoleptic changes which occur the first five days poultry is held at cooler temperatures (30-40° F.). These changes were first observed by Hanson *(2)* in broilers. Later work has shown that the changes also occur in fryers, roasters or fowl. The time required to produce the changes in tenderness (though not flavor changes) varies among the classes of poultry, being most rapid in broilers and slowest with fowl (hens). In addition, the time to produce tenderness varies from muscle to muscle within a given class. Breast muscles tenderize more rapidly than the thigh muscles. Coincident with the changes in tenderness extensive histological alterations can be readily demonstrated. (Figs. 5 and 6.) In frozen birds histological technics have also permitted a better understanding of the nature of "dryness" (saw-dust texture defect, not to be confused with dryness as the result of moisture loss) observed to develop in poultry during frozen storage. Fig. 7 shows the comparative differences in the histological structure of "dry" from normal meat.

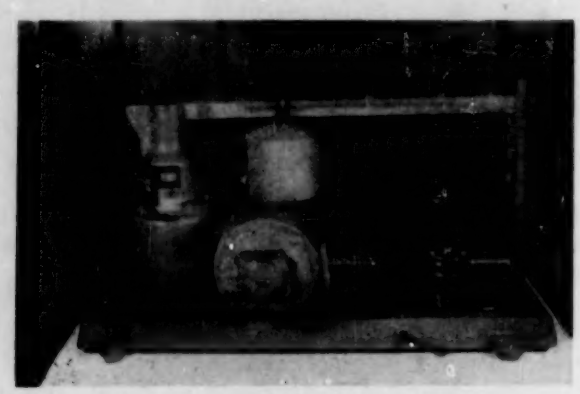

FIG. 3. The pressometer (Child and Baldelli).

Technics employing measurement of the moisture vapor-pressure moisture content characteristics of the tissues are also being used to study this "dry" defect.

f. Fat characteristics. The fat content of poultry meat is an important factor in determining its flavor and juiciness. Fat oxidation during storage of poultry meat may lead to off-flavor development. However, it has not yet been possible to interpret the quantitative chemical changes which occur in the *in situ* fat during storage with the odor and flavor changes of the meat.

g. Moisture. It is obvious that the moisture content of poultry is a factor of importance in determining its acceptability because of its relationship to juiciness and possibly other factors. Poultry which has been excessively desiccated during storage is unpalatable. Moisture losses also occur (and consequently dryness) during cooking. The moisture losses during cooking are controlled, to a great extent, by the length of the broiling or roasting period. To record and standardize the cooking time a specially-made, short thermometer or a thermocouple inserted into the thigh muscles is used.

h. Miscellaneous. The possibilities of other objective tests are constantly being explored. Evidence has been obtained which indicates that tests for enzyme activity might prove useful in studying the nature of the organoleptic changes

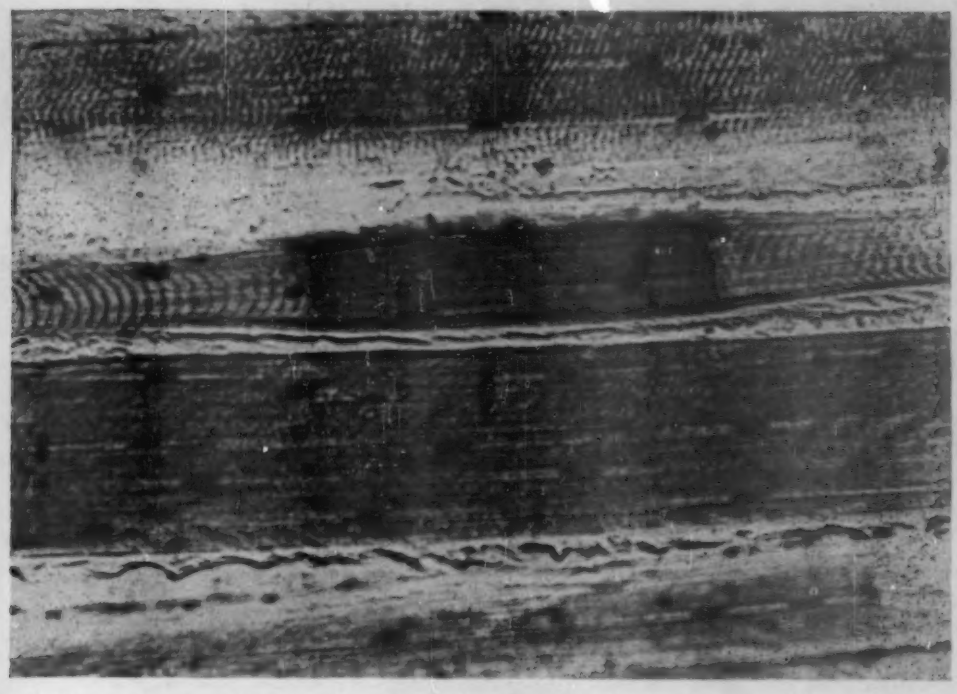

FIG. 5. Compressed node and stretched internodes of rigor in breast muscle fibers of broilers. In this condition the muscle is extremely rubbery, stringy and tough. Longitudinal section. Mag. approx. 825×.

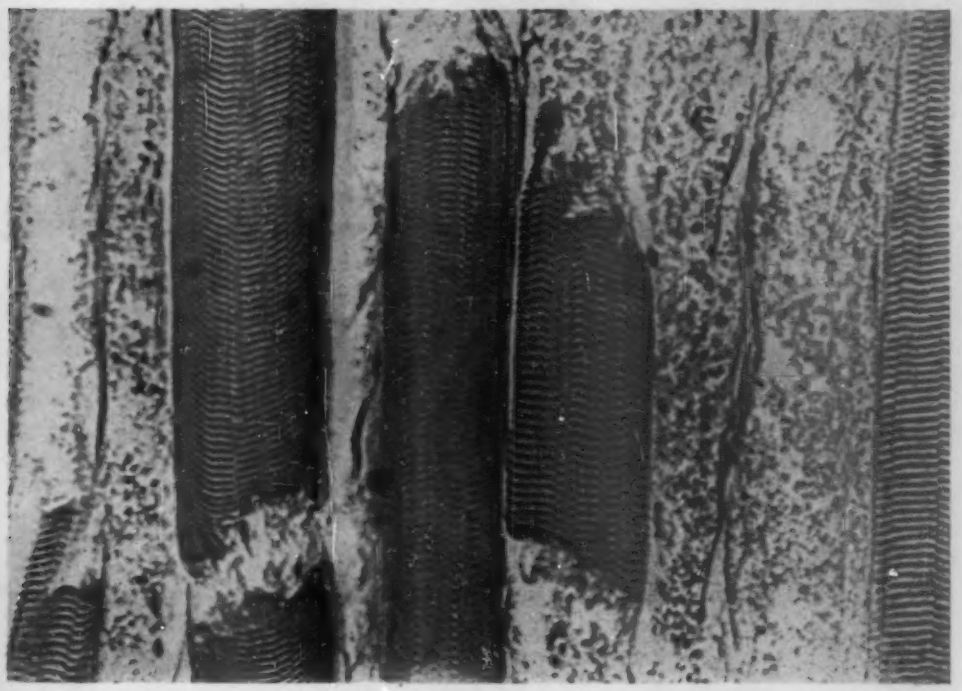

FIG. 6. Disintegration of muscle fibers accompanies the increasing tenderness of muscles during the aging of poultry. Longitudinal section breast muscle of broiler. Mag. approx. 825×. (Figure previously published in Food Research.)

occurring in poultry meat during storage. Microbiological spoilage occurs in poultry meat under certain storage conditions. The organoleptic characteristics of such spoilage are quite readily detected. Systematic microbiological investigations are warranted when microbiological factors are involved, in order to determine the exact course of the spoilage and to establish ways and means for its control.

FIG. 7. Disintegration of the elastic fibers (the criss-cross dark lines) during frozen storage characteristic of "dry" meat, particularly the breast muscles. (Figure previously published in Food Research.)

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FOOD ACCEPTABILITY — ITS DETERMINATION AND EVALUATION [1]

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THE NATURE OF THE PROBLEM

Food Acceptance Research professes to measure man's private opinion on the edibility of foods. Under the usual circumstances of peacetime living these private or individual opinions on the edibility of foods take numerous forms. For example, in a recent national food survey there were over 800 items listed, each with numerous ways for its preparation, and one might compile 99 ways to serve potatoes and 53 or more ways to prepare and turn eggs. There are also numerous varieties of the same food; for instance, there are 6500 horticultural forms of apples and 500 or more varieties of potatoes *(1)*; and there are innumerable brands of every processed, marketed, and labelled food.

Out of the permutations and combinations of so many different food items with the numerous different and separately preferred methods of preparation, differences in kind and variety and brand, men are able to express degrees of freedom and difference perhaps not equalled in any other sphere of their existence. Although each individual gradually confines his freedom through custom, habit, and availability of supplies to a limited range in expression, nevertheless each individual is able to differ according to his likes in food from his neighbor, perhaps far in excess of his freedom to differ in clothes, education, clubs, and religion.

Thus, when war comes it is easier to dress men alike, even though they come from different regions, with different social, economic, and cultural and racial origins than it is to feed them alike. While the mother of the family may facetiously refer to father's stubborn food-habits, Uncle Sam, as chief chef of the civilian-recruited Army of men, must know how to serve foods which all men will accept. That is the major "Operation Culinary."

During the war just ended, the soldier-consumer was provided with a ration calculated by nutritionists as complete and supplying the minerals, vitamins, proteins, fats, and calories required for bodily needs at heavy work. But when the soldier refused to eat some of these food items and threw them away, he failed to receive the nourishment calculated as supplied to him for the work required.

Food acceptance research is based upon fundamental biological principles irrespective of war or peace, but the conditions of feeding large groups of men on prepared rations for long periods of time were destined to bring out into the open certain needs for survival, which demonstrate the purpose and functions of food acceptance research by means of an up-to-the-minute example.

Long before the war many separate islands of research relating to food acceptance had been studied in the research laboratories of both universities and industries.* The war merely helped to re-emphasize the need for integration and made

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[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 16, 1946.

* The reference to this literature is voluminous and widely scattered. Several disciplines are concerned with the subject—each with its particular emphasis and interest. The subject has its literature in anatomy, physiology, psychology, genetics, statistics, as well as chemistry, to name a few. Nine years ago the Symposium on Flavors in Foods held by the American Chemical Society (Food Research *2*, 183-286 [1937]) stimulated application to Commodity Testing.

possible a fresh approach. This approach, we wish to indicate, may be made through cooperative action of present existing specialties plus new techniques of a Science of Food Acceptance *(2)*.

It should be noted to begin with that these ration items, refused by the soldier, had all passed Federal or Army specifications. Each food, according to its kind, had measured up to the Standards of Identity, the Standards of Quality, and Food Grade Standards, as supplemented by the specifications of the Quartermaster General. Federal and/or Army food inspection officers had passed upon the foods as raw or fresh materials from the farmer or producer and had passed also on the final product according to written specifications for the food processor or manufacturer. These latter inspection services included in many instances sampling of the production line and submitting these samples to chemical, vitamin, and microbiological tests before the procurement officer approved the purchase. Furthermore, at the time of distribution of the foods in the dining barracks or at the front, the mess officers and the food inspection officers checked upon the quality of the food as received, prepared, and served.

A food produced according to Definition and Standard of Identity represents the very lowest level of quality at which the article is entitled to be sold under the defined name *(3)*. But to pass Standard of Quality a grade above the minimum is specified whereby purity, strength, flavor, color, size, condition, and other consumer measures are included. Finally, according to United States Food Grade Standards, each food is given a score card type of rating whereby both subjective and objective measures of quality are usually employed.

And yet, in the face of all of these safeguards for quality, foods were refused. As is well known by those who participated in the campaigns, certain ration items paved the roads to the front lines and filled the gutters along the detours.

The cause of the refusal of certain food items by the soldier-consumer represented something therefore that could not always be measured either by the nutritionist in terms of the chemistry of vitamins, calories, minerals, proteins, or fat, or by the food technologist in terms of contemporary objective tests for tenderness, compression, viscosity, pH, etc., or by subjective tests for flavor and quality, or by score card ratings. These methods had all been applied—and yet food was rejected.

Such an appraisal of the status of the problem is essential background for delineating a possible way out and for indicating the direction that research should go if acceptability tests are to pass the acid test required of them. Are we to find the answer in nutrition, in chemistry, in food technology, in quality appraisal, or in psychology? Are we to improve the techniques in each of these fields separately, or must a new approach be made through new techniques which represent a common denominator to each and all of these disciplines? The latter method we wish to explore here.

Our purpose, then, is to learn how to measure those characteristics of foods or the consumer of foods (or their interactions) so as to supplement the present qualitative appraisals and thereby increase the probability that food will not be wasted, that the consumer will accept the food and be satisfied thereby.

In devising techniques for the determination of acceptability, we have sought the combined experience of many persons who have been interested in one or more aspects of testing food for quality, *i.e.*, in the psychology and physiology of appetite and hunger, in taste and flavor tests, in psycho-physics, in psychometrics, in organoleptics, in food habits, in food preparation, and in statistics of populations, to name a few. Such an approach is necessary since the correct interpretation of non-acceptance of a food doubtless does not rest upon any one specialty.

As a result of the experience of the Army Service Forces with rejection of foods, a new branch was established in November, 1944, at the Chicago Quartermaster Subsistence Research and Development Laboratory for the designated purpose: To discover the causes of non-acceptance of foods by the soldier-consumer and to develop techniques for measuring and evaluating acceptability. By this means foods destined for the rations had to be tested for acceptability *before* they went into the rations.

In the interval since that date more than a thousand foods or items have been tested for acceptability. They include every food class and are potential supplies for rations of all types—whether for barracks, for field operations, for emergency conditions, or for hospital use. The majority of the items tested (and certainly the techniques) have immediate applicability during peacetime to the Army as well as to the civilian consumer.

An abbreviated list of some of the food items tested to date indicate the range and nature of the problems:

(01) *Vegetables.* Canned food storage study: green beans, lima beans, carrots, yellow corn, peas, spinach, tomato juice. Potatoes: small, canned, boiled, Irish potatoes; candied sweet potato samples varying in concentration of sugar syrup added. Soup: bean soup, high fat, dehydrated; C-Ration, vegetable soup; samples of soup stored a year at 70° and 100° F.; beef broth; chicken-noodle soup; dehydrated green pea soup; dehydrated pea soup with beef and pork concentrates added; oatmeal chicken-style soup mix. Succotash: corn and soybeans compared with corn and lima beans. Tomatoes and corn, served with canned beef. Preference order of commercial brands of vegetables: tomato juice, green peas, kernel corn, diced carrots, green beans.

(02) *Fruits.* Canned food storage study: apricots, orange juice. Apricots: dehydrated (color vs. acceptability); dried (Camp Lee long-time test) vs. canned. Cherries (dehydrated). Fruit bars: varieties of fruit in fruit bars. Fresh frozen orange juice. Prunes: two kinds in a pie. Oranges: Florida-grown compared with California-grown; dehydrated orange juice powder compared with canned. Apple juice.

(03) *Nuts.* Peanuts: types of packaging for Assault Lunch (storage study); long-time study of types of pack and temperature differences; package and storage study—half stored at refrigerator temperature and half stored at 100° high humidity; Spanish vs. Virginia—blanched vs. unblanched.

(04) *Cereals.* Bread: bitterness test of wheat vitamin concentrate in canned bread (storage study); fresh, Army style bread—to study palatability changes on flour stored at room temperature and 100° F. Biscuits and crackers: six samples Type V crackers; commercial soda, graham, Army graham, Type V soda, soy grit graham; three samples of crackers, identical except for amount of bake; crackers fortified with bone phosphate; soya wheat soda cracker against Type V soda cracker; Type IV biscuit—salted, paired with plain; types of biscuits packed in rations; cheese crackers—color preferred. Prepared cake mix. Cereal: premixed cereal fortified with synthetic thiamin compared with unfortified; three premixed, ready-to-eat cereals—regular, citric acid added, and more citric acid added; new premixed cereal and two standard premixed cereals; a special sample of uncooked wheat cereal compared with a standard; uncooked wheat cereal (acceptability); preferred kinds of whole grain cereal. Cookies: butterscotch- and chocolate-filled sandwich cookies—filling fortified with vitamin C at different concentrations. Noodles: plain, Army style (storage study). Types of pancakes: mix made from three different flours; canned pancakes to be used as a ration component. Rice: substitute for rice served with a similarly prepared rice product; seven samples of rice tested for preference.

(05) *Meats.* Beef: Effect of tenderizing process on acceptability of choice, good, and commercial grade beef; frozen, precooked roast beef; frozen precooked roast beef—to determine whether cooked meat should be frozen with or without gravy; dehydrated corned beef hash; boneless, chopped, frozen beef; beef ground through different size plates. Frankfurters and bologna: storage study of six kinds. Ham: war ham (rating scale); ham and raisin sauce; ham, potatoes and gravy. Chili-con-carne: two types—laboratory-prepared, high spice sample and commercially-prepared, low spice sample. Meat and rice dehydrated: storage study to determine if added pimiento and dehydrated tomato reduce keeping time of the product. Pork and rice, dehydrated: high onion seasoning compared with less onion seasoning. Pork and corn/beef and corn. Pork luncheon meat: experimental sample with special spices compared with

commercial run, secured from market. Sausage: pork sausage, frozen—storage study to test effect salt and seasoning have on storage life of fresh pork sausage; bologna style sausage—two types; salami sausage—two different smoking times. Spaghetti and meat, canned: four different preparations of spaghetti. Spam: breaded meat slices (recipe test). Frozen precooked food: storage study. Eggs: powdered eggs, processed by a new technique; two year old dehydrated egg sample, presented in cake and compared with cake made from a fresh egg sample; hardboiled, canned eggs (served in three different ways). Egg porridge, canned: three samples. Chicken: solid pack, canned chicken—to determine the acceptable amount of fat that can be included (storage study); 1 year old chicken, frozen by a special method; overseas, Army style chicken stored at 0° for six months; chicken and turkey meat and fat—boned, canned; chicken and vegetables—existing C-Ration item with green peppers paired with sample without peppers.

(06) *Dairy Products.* Butter and oleomargarine: comparison of the two; preference order of brands of high melting; butter flavor—added to shortening. Cheese: processed American cheese fortified with Vitamin A (storage study); processed American cheese fortified with thiamin and yeast (storage study); cheese spread with ham and relish (storage study); processed American cheese fortified with dried, primary grown yeast at four different levels. Ice cream: ice cream mixed with soluble coffee. Canned food storage test: cheese spread; Army spread; evaporated milk; Klim dried whole milk. Milk: evaporated Pet milk fortified with vitamin A (storage study); reconstituted, dry, whole milk—various fat contents (storage study); canned chocolate milk drink; dry whole milk flavored (maple, chocolate, coffee, strawberry) and presented with a control of plain milk; dry whole milk reconstituted by field equipment for hospitalized patients; dry whole fresh Enzylac.

(07) *Fish.* Acceptability of three types of canned fish, *i.e.*, lake fish (tuna style A), lake fish and rice (Spanish style), lake fish (tuna style B).

(08) *Confections.* Candy bars: cocoanut and chocolate bar; three kinds of Mars bars. Malted milk tablets. Puddings: preference order of puddings in rations; two samples of a commercial product; three samples of plum pudding served hot and cold for acceptability. Syrup: chocolate, orange. Candy in Air Crew Lunch—desirable assortments.

(09) *Beverages* (other than milk or fruit juices). Beverage bases: cherry, raspberry, acid—sugar ratio. Coffee: soluble coffee sample fortified with ascorbic acid compared with the unfortified; vacuum, compressed coffee; quality of warehouse coffee for hospital use. Eggnog: recipe test. Malt preparations: cocoa beverage powder—fortified with ascorbic acid; chocolate malted milk.

(10) *Condiments and Flavorings.* Catsup: three varieties of dehydrated catsup. Cinnamon: natural and imitation tested in cinnamon rolls. Gravy: powdered meat sauce. Mustard mix. Sugar: fortified with ascorbic acid.

(11) *Gum.* Gum: acceptability of different samples.

Rations. Life Raft, Assault Lunch, Air Crew Lunch, Ten-in-One, items in the C and K Ration.

Miscellaneous. Shortening—high stability; meat tenderizer—to determine its effect on the acceptability and palatability of grade C utility beef; Spramalt product served in caramels; V-Manna concentrate served in soup; Richen Multi-Purpose food—served in soup, stew, and meat loaf; Glutamate—served in scrambled eggs made from dehydrated egg powder; vegetable-protein formula—served as a hamburger mixture.

DETERMINING ACCEPTABILITY

Out of the personal experience prior to the war *(4)* of devising methods for measuring acceptability of regionally-adapted foods and out of our experience in testing food items destined for Army rations, certain general principles have gradually evolved which, if followed, clarify discussion and reveal some order out of chaos.

Each food presented for acceptability tests is a problem in itself. Before an appropriate test is made, background information from the commodity specialists and other sources must be secured. Acceptability tests cannot be compared with chemical tests, as for vitamin or sugar content. The word acceptability implies a full measure of behavior and it is behavior that we must also measure. To do so correctly requires far more background information on methods of production and potential future usage of the food than is required on foods submitted for the usual biochemical or bacteriological analysis.

While numerous methods have been tried in this laboratory, nevertheless the type of test most widely acceptable to all foods of all classes falls under what we have decided to call the "Subjective Objective Approach." The use of these two terms in combination now becomes necessary since the trend in research has been to depend solely upon the objective approach, whereby all measurements, whether of a physical or chemical or mechanical nature, are directed toward the food and to discredit the subjective approach, which deals with man's personal physiological or psychological responses. We believe this emphasis to be misleading. Furthermore, we wish to raise the subjective measures to a quantitative level. By this means we expect to quantify and to standardize the measurement of subjective responses, so that they may then be combined with objective tests whenever possible.

The current desire to secure objective measurements of the food as the acme of scientific methodology in quality control has tended to neglect the fact that all measures of value of a food must, in the end, be liable also to the subjective response, in terms of "yes" or "no" or "maybe" by the consumer. In our zeal for scientific accuracy whereby all things must be reducible to millimeters, milligrams, degrees, wave lengths, as measured by machines, we have failed to keep in view the end-use for which foods are procured. One authority considers that we have advanced in inspection methods, because now "specifications are determined objectively, without too much reliance upon the personal reaction of the one making the inspection." In reality, this conclusion merely indicates that we have made no attempt to quantify the individual responses of the inspectors.

The moving spirit of the last decade in food technology is epitomized by an authority, writing in 1939, who says: "One of the cheering signs of the times is the number and kind of objective tests being developed and used for judging or, more properly stated, measuring the properties of cooked food." In general, the decade has been very properly imbued with caution for the very real fallacies of individual subjective judgments. The way out was thought to be a disregard of the subjective, and concentration on the objective. During this past decade, in order to facilitate the physical measurements of quality, there have been devised, invented, or improved hundreds of objective methods of testing for quality in foods. These methods include: chemical tests of pH, sugar, astringency, bitter principles, coagulation, oxidation; physical tests for crushing, foaming, whipping, breaking, puncturing, twisting, compressing, for mealiness, firmness, stiffness; photographic methods, X-ray techniques, use of the fluoroscope. For food tests there have been developed: colorimeter, consistometer, jellometer, penetrometer, polar planimeter, pressometer, sagometer, shortometer, spherometer, stinkometer, tenderometer, and the schnittfestigkeit. Each piece of equipment and each chemical or physical test has been created, presumably, for the primary purpose of recording scientifically man's reaction to food. And yet, it must be clear to everyone that each and every instrument must be given a final value in anthropomorphic terms: How much shortened? How tender? How viscous? How firm? How astringent? How bitter? How sweet? That value has not been assigned. And if we regard the individual differences in the replies to these questions as an incoherent jumble, it would appear that we have sharpened our tools for tests of the object, but have left the most important measure—the subjective response—in a rough and unusable stage whereby each expert can express only his own individual subjective opinion loudly. There is therefore great need for the development of methods for quantifying the unharmonious vociferations of the judges and even of the consumers to be served.

The subjective-objective approach, then, is the first step to be taken in our re-orientation before we can develop food acceptance tests. And before we can

possibly judge the merit and range of use of each and every objective test, we must hunt out a scientific basis for our judgment by developing a method of measuring the subjective responses.

Briefly stated, we are concerned with the subjective-objective relationship as an interaction. For convenience in discussion of acceptability testing, we may break down the subjective phase of the S-O approach into three major endeavors:

1. Laboratory Tests: The difference-preference tests, panel tests, luncheon tests, barracks tests, field maneuver tests; threshold tests; the interrelation of these tests to each other, to preferences and attitudes, and to physical status; statistically-sampled opinion from the field of operations in action, or from civilian consumers.

2. Tables of Experience: or Subjective Quality Control.

3. Appetite Levels of Food Consumption: Regional and National Consumer Surveys for acceptance rates, the preferred methods of preparation and serving, the preferred varieties and kinds, and the psycho-physiological attitudes for or against each of a national list of foods.

Since laboratory tests are perhaps of more interest to this group, I shall spend somewhat more time upon that phase of the problem. Parts 2 and 3 are, however, equally essential to the final evaluation of acceptability of single food items.

I. LABORATORY TESTS

The Difference-Preference Test. What we here term the Difference-Preference Test provides a basis for quantifying attitudes and judgments, and prepares the way for subsequent comparative tests with all objective measurements. Alternate movement is essential to progression; so too in science, the alternate emphasis upon the subjective and then the objective will in the end fuse into one process whereby all unessential objective tests and all incoherent subjective responses will be exfoliated and fall into discredit and disuse.

For the purpose of quantifying subjective tests, closer attention must be given to details than is usually considered necessary in quality appraisal and scoring for standard grades. There is no intent in devising food acceptability tests to add to the portfolio of food inspectors or food graders. There may be some need to add new measures for grading quality not already in use but food acceptance tests are in addition to these and are as separate from food-grading as are soil fertility studies, vitamin analysis, or food menu planning. Food acceptance tests form one of the missing links to ensure consumption of the final product and, while they must be developed as a separate link, in the series of tests made upon foods, they must at the same time serve as a link in the active sense of the word.

All laboratory tests are divided into at least two aspects: (1) to detect differences; (2) to determine which difference is preferred. Records of difference and preference are taken consecutively upon the same food samples.

In order to quantify these subjective responses, we must follow careful psycho-physical techniques. Some important features of the testing laboratory, as we have designed it,* are as follows:

a. The laboratory is entirely air-conditioned, since the occasional odors of paint, coffee, smoke, factory or storage fumes and aromas prevent the accurate detection of differences.

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* The Food Acceptance Research Laboratory, Quartermaster Depot, Chicago, was designed after a study of a number of food and beverage testing laboratories of the country. The requirements of feeding a national army on natural foods necessitated the development of a laboratory different in many respects from those used chiefly for beverage appraisal.

b. The food preparation kitchen forms the center of the laboratory unit, since careful control for temperatures of serving, uniformity of conditions for serving, and cleanliness, are required in the detection of differences. The kitchen also provides for the development of new products from the raw ingredients as suggested by panel judgments.

c. Individual panel booths for the food judges are in proximity to the preparation center, in order to facilitate serving the test items in a uniform manner.

d. The individual panel booths allow for the segregation of the judges in order to ensure separate individual responses and prevent comparison of responses before they are recorded.

e. The booths are provided with simple food disposal fountains, since food testing may be halted without this facility.

f. The walls, table tops, accessories, etc., are of a natural gray, which does not add color to the foods.

g. The panel booths are equipped with a spot-lighting system whereby three degrees of natural light and two degrees of colored lights (red to blue), plus control of intensity, are provided. By this means the response to color differences may be either augmented or eliminated. By this means, also, the gustatory judgments based upon color differences may be separated from those based upon flavor differences. Food may be accepted upon first presentation on the merit of color or eye-appeal alone; but, if the food does not have taste appeal as well, it will doubtless become less favorably accepted with each succeeding presentation. By means of color control, we may be able to add both taste and color appeal to the food, and thereby insure first acceptance, as well as continued acceptance.*

h. The panel booths are five in number. By this number, two series will provide the ten records required of a carefully selected group of judges. One booth alone would not make possible the simultaneous testing of a hot liquid, like soup, since soup changes consistency if held for the length of time required for a test by a panel of ten judges successively in one booth. One test operator can attend five subjects efficiently at one time.

i. The laboratory is provided with a small dining room where tests for difference-preference may be made when the test food forms part of the meal. Detection of differences and preferences may be modified in some instances by the foods with which the test-food is combined. When a food is tested in context with the meal, it gains more significance as an item in the ration for which it may be intended.

j. A physical-chemical laboratory also provides for: (1) tests for thresholds of gustatory sensitivities of potential judges; (2) apparatus for use in chemical and physical objective tests on the same foods submitted to subjective tests.

k. The laboratory has access to food storage rooms of differing temperatures and humidities.

l. Cooperative arrangements are available for chemical, vitamin, mineral, bacteriological, and packaging tests.

m. All tests are carried out in a laboratory separate from those concerned in any way with development of the product or its container; yet the research is a cooperative venture whereby technologists, commodity specialists, and packaging

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* This use of colored light for the elimination of color differences was developed with the cooperation of General Electric Company, Cleveland, Ohio, and has been adapted in part from experience by the writer in using red lights in the prevention of cannibalism in experimental animals (7).

specialists join in the discussion of the purpose, plans, and conduct of the experiment so that the appropriate statistical design may be set up for results statistically significant.

n. Provisions are available also for the extension of the tests to larger consumer groups—to barracks, concentration centers, field maneuvers, flight tests, and finally to actual use in the field of operations or in civilian consumer tests.

Some important features of the test for differences:

1. The foods:
   a. Small samples of foods are used. The samples must be large enough to reach all taste organs of the buccal cavity and yet not so large as to cause fatigue.
   b. Different temperatures of the foods bring out different tastes and different responses to texture, juiciness, etc.
   c. The presentation of foods in pairs accentuates differences that exist.
   d. All test foods are given a hidden code number. Information on the origin and purposes of the test for differences is withheld from the judges.
2. The judges:
   a. Any normal individual may possibly make a good judge of differences, regardless of his previous experience with the food.
   b. Although experience may assist the judge in verbalizing his responses, experience can never make up for an innate lack of the sense of taste or smell. Since judges are selected only on the basis of a consistent recognition of small differences known to exist in the foods under test, the judges finally selected for the panel may or may not represent specialists in the particular food used for test.
   c. A judge is selected on his ability to detect small differences in a series of paired samples of the same food, one of which may have been held at a higher temperature, or subjected to greater concentration or dilution, or exhibit such differences as exist between varieties or between different recipes, or show the effect of differing methods of harvesting, preparation, cooking, seasoning, canning, or storage. A good judge will recognize eighteen or more pairs out of twenty pairs; while a person who cannot recognize the differences will give a record similar to a person guessing, *i.e.*, ten to ten, or slight variations about equality.

      The methods of securing differences should be appropriate to the nature of the test and are innumerable. This method of selecting judges differs from that of selecting on the basis of acuity to the four primary tastes—salt, sweet, bitter, sour—although correlations between the two methods may some day be discovered.
   d. The judges are asked to define the differences when detected. The language of differences serves as a key to the physical or chemical differences existing in the original material or arising during storage of the product. From the words used by the judges to describe the differences detected, the product may be revised accordingly. By this means a non-acceptable product may be remade to be acceptable.

Several other methods for detecting differences besides the paired method may be used. These include serial order, single or constant stimuli, and differences accentuated through conditioning.

Some Important Features of the Record for Preferences. The second facet of the Difference-Preference Test is to ascertain which of the two differences is preferred. Records of both characteristics (differences and preferences) are taken one after the other at the same sitting. The analysis of differences represents a study of individual abilities, while the analysis of preference is a problem in populations, and includes all the peculiarities of likes and dislikes that go with populations of mixed peoples.

When differences are discovered, those differences gain importance only when translated into preferences. If the two foods cannot be distinguished as different by the gustatory sensitivities, or if different and no preference exists for one over the other, then the foods are legitimate substitutes one for the other. But a preference expressed by the majority or all of the panel for one sample as against the other indicates the direction production should go if the judges represent the population to be supplied with the food.

This is a big if and calls for the information being secured under Part 3 on Food Consumption Habits and Consumer Surveys. The best judges in detecting the same differences may have opposite attitudes toward these differences, *i.e.*, Judge A may prefer the sharp change taking place in the cheese spread during storage at high temperature, while Judge B may thoroughly dislike the same change taking place and prefer the mild flavor of the green or fresh cheese. Here then the relation of the opinion of the panel group preference to the distribution of preferences within the population to be fed must be known or must be calculated from reliable sources.

In order, then, to place a yard-stick on the preference phase of acceptability tests, two new measures have had to be developed: (1) attitude records of the judges to serve as individual standards of reference; (2) measures of regional and national attitudes toward a national list of foods to serve as food standards of reference.

In a break-down of Part 1 of the preference record we have included several measures of intensity in each test, to serve as standards of reference:

a. Degree of acceptance usually experienced: How do you usually consider the particular kind of food under test? Is it very good? Is it good? Is it liked well? Is it tolerated only when hungry? Is it disliked? Does it make you sick or cause allergy or has it never been eaten before?

b. How do you rate this particular item?

c. Is the item the same, better, much better, poorer, or much poorer than usual?

d. How many servings of the item would you desire per week?

The first three measures represent triple-checks and serve as standards of reference to past experience. The fourth represents a quantitative measure of an attitude. All four references are typical of the subjective responses of individuals to foods they like or dislike, and yet they represent an approach to the quantitative response measurement necessary for statistical treatment.

In some tests the conditions dictate the use of a single scale representing ten units for the purpose of recording the pairs of differences in terms of degrees of preference. By such a method, five equal degrees of acceptability and five equal degrees of non-acceptability are allowed. By either method both differences and degrees of preference may be measured in absolute and in relative units on the same foods at the same time by the same judges. The results may be treated graphically with the level of acceptance clearly established *(8)*.

The difference-preference test is also adaptable to acceptability tests made by the use of experimental animals. Foods like lettuce, kale, cabbages, and other cruciferae may, by their occasionally strong flavor, confuse the human tester. For these types of foods, animals serve well as taste testers *(9)*. Furthermore, laboratory animals may be used to detect off-flavors in dehydrated foods, as in dried peas, oat feed, or alfalfa leaf meal *(10)*. A special technique has been developed for such animal tests whereby the pattern of the complete diet is held constant while the attention of the experimental animals is directed to the detection of differences and preferences between two test items or between a test item and a standard, both of which are presented at the same time *(9)*.

2. TABLES OF EXPERIENCE OR SUBJECTIVE QUALITY CONTROL

The data secured from the difference-preference tests represent quantitative measures of sensory impressions and of attitudes expressed as standards of reference. As long as subjective data lacked quantitative expression, just so long were they too variable and unreliable to possess predictive value. Under those conditions, subjective reactions had no accumulative value.

However, by refining the psycho-physical techniques of the laboratory and devising quantitative records on attitudes, we may secure consistently repeated results. Under these conditions, Tables of Experience are being built up to serve as a Subjective Quality Control. Thus a year's records of the panel on reconstituted dried whole milk make it possible to evaluate any new test on milk dried by any new method. The Tables of Experience may also be used to check on the continued production of an accepted item. Such experience tables also reveal classes of foods which are consistently rated low—such as apple juice made from waste dessert apples or from untested blends of apples never intended for cider in the first place. In other words, the Tables of Experience represent another tool which will continue to reveal the acceptable foods as well as the chief problem-foods or problem-conditions of processing, packaging, or storing and will assist in predicting the success of an item before it is included in the ration or placed upon the market.

3. APPETITE LEVELS OF FOOD CONSUMPTION

Appetite Levels of Food Consumption represent data on the regional-national likes and dislikes for each of a national list of foods—their rate of acceptance; the preferred method of preparation and mode of serving; the preferred varieties, brands, or kinds; and the favorable and unfavorable combinations and psycho-physiological effects attributed to each *(11)*.

These records serve a multiple purpose in addition to their use in determining the territorial range in acceptability of any single food item. The records should provide the information as to what foods and what preparation methods are nationally preferred. This information is essential to the designing of operational rations for the Army and for food industries dealing in a national rather than a regional product. National foods should serve as the core diet for military, civilian, and governmental food programs.

Furthermore, the records should reveal the regions in the country which produce the preferred products and preparation methods. This information is of value to both food processors and Army procurement officers. We might follow faithfully all of the procedures in testing for acceptability up to the panel records and approve the food and yet be misled in the final judgment. Hence the necessity for regional vs. national measures of what is an acceptable food item.

One of the frequent causes of first refusal of food in the Army was lack of acquaintance with the food or an unfamiliar method of preparation. A food may pass with a high rating for acceptability by those who are accustomed to it, and yet be rated low by those from regions unfamiliar with the food. Furthermore, a single variety of food (apple, for instance) may grow luxuriously in one region and be highly acceptable; and yet may be tasteless or unacceptable when grown in another region.

In order even to answer the question, "Is item 'A' acceptable?" one must relate the preference response of the panel of judges to the consumer for whom it is intended. By this means, tests of preference, the degrees of preference, and the preferred method of preparation and serving, as stated by the judges on the panel, may be compared directly with regional and national data for the same type of record secured from samples of the population as a whole. This reference material is being assembled through cooperative projects throughout the country through the Committee on Food Research and the Food Acceptance Research laboratory.

CONCLUSION: EVALUATION OF ACCEPTABILITY TESTS

Acceptability tests, according to the foregoing description, include: (1) laboratory tests; (2) subjective quality control standards or tables of experience; and (3) regional and national surveys on appetite levels of food consumption (a form of consumer attitude survey). In the administrative policy of several national food industrial laboratories, frequently only one of these duties may be carried out, such as, for instance, laboratory taste tests. Quality control is usually left to Federal or U. S. D. A. marketing specialists, while consumer surveys, as now taken, are generally delegated to a separate agency, such as an advertising agency. Advertising agencies are especially active in evaluating consumer opinion on acceptability of the food item prior to an extensive advertising campaign.

Administratively, however, and aside from the improvement of each of the three methods of testing foods for acceptability, it appears clear that these three methods should not be carried out under separate supervision since the final answer on acceptability of any single food item must be interpreted in the light of all three: laboratory tests, tables of experience, and consumer surveys. Misleading results may often be attributed to over dependence upon only one of these methods of testing for acceptability.

When acceptability tests are designed and supplemented as indicated in the foregoing account, they may be used for a multiplicity of purposes; therefore, in the development of the techniques, the end-purposes must be kept in mind and provisions for these uses must be woven into the structure of the test form.

A brief and running list of some of these uses include the following:

1. To develop new products. The panels indicate preferred composition and specify the nature of each ingredient as well as the pattern of the ingredients (recipe) *(12)*. For instance, a new Army fruit bar was developed on the basis of comparison with the C.Q.D. Specification Standard Fruit Bar. The panel indicated what kinds of fruits were desired, their ratio one to another, their combination with nuts added at a certain level, and of a preferred variety.

2. To supplement quality appraisal and food grade standards. Canned foods of identical quality grade and price have different acceptability ratings. Foods standardized for size grade may differ in acceptability and even ungraded peas may be highly acceptable and may represent an ideal combination of sweetness and tenderness plus substance *(4)*. The food score card needs to be studied statistically in order to place values for color, flavor, texture, etc., in keeping with acceptability tests.

3. To direct food preparation and serving method. The method of preparation of foods represents one of the keys to food acceptance. Under conditions of war it was "home-cooking" that was desired. While the desire for home-cooked foods might appear to be an obstacle to improving food habits, nevertheless there is evidence to indicate that the preferred method of food preparation as secured from population surveys could serve as a standard for changing and improving food habits.

4. To indicate optimum packaging methods and shelf life. In many instances packaging methods and the nature of the packaging materials are more important in the retention of flavor than the effect of antioxidants added to the food for the purpose of retaining flavor after long storage.

5. To reveal the best time and methods of harvesting, processing, and storing. A carefully selected taste-panel is able to detect changes in stored foods a month or so before objective chemical methods reveal those changes.

6. To provide direction to genetic selection of varieties of foods and thereby balance the present vogue of selecting for high yield and disease resistance *(9, 13)*.

7. To supply the advertising bureaus with substantial gustatory appeal to supplement the more apparent eye appeal.

8. In the end, to indicate in part the direction research may go to fulfill the psycho-physiological and nutritional needs of the population. The studies on preferences and the intensities of the preferences and prejudices make it possible to separate nationally-preferred foods from those regionally preferred.

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WARTIME IMPROVEMENTS IN RODENT CONTROL AGENTS [1]

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"Compound 1080" and "ANTU" are code names for two of the new chemicals developed during World War II. The first of these was an outgrowth of studies conducted within the chemical warfare agencies of Great Britain and the United States; the utility of this compound as an economic poison had been unsuspected. The second material was made specifically for use as a rat poison.

The story of how these chemicals were discovered and tested as rodenticides involves a great many interesting details. First, it is well to recognize that the intensive search for new poisons was a true wartime program. Early in the war it became apparent that the supplies of some of the most effective agents were going to be extremely short, and that there was grave danger that some of the materials would be entirely unavailable. Among those likely to be scarce or even unavailable were thallium, strychnine, and red squill—poisons which had proved to be the most effective agents in the control of many species of noxious rodents. Shortages of these products would not have been too serious for the civilian population, though the reduction in effective control of rats and field rodents would have resulted in increased loss of valuable food and would have raised the incidence of rat-borne disease; but the armed services faced a different situation.

Fighting a world-wide war, the United States had to send expeditionary forces into foreign areas where little-known hazards existed. Men from this country went into combat in areas where bubonic plague, tsutsugamushi disease, and typhus fever were common. Army and Navy officers always tried to anticipate trouble and to provide means of combating it. One of the first questions raised dealt with adequate supplies of effective rodent poisons, and inquiry indicated a critical situation in regard to thallium. The problem was referred to the Office of Scientific Research and Development, and it was found that two agencies in the United States had been aware of the impending crisis and had started to do something about it.

The first of these was Johns Hopkins Hospital in Baltimore. While conducting some studies on animal behavior, Dr. Curt P. Richter of that institution had found that phenylthiocarbamide (a chemical frequently employed in making tests on taste reactions) would kill his experimental animals. These small creatures happened to be common albino rats. It occurred to Dr. Richter that such a chemical might be very useful in the control of wild rats, which were receiving considerable attention in Baltimore at that time—aside from being pests in every part of the world. As he continued these tests, he became convinced that the idea merited careful and detailed study, so he applied to the Office of Scientific Research and Development for sufficient funds to support the project. The request was granted and, in addition, the assistance of the research laboratories of E. I. du Pont and Company was enlisted.

The major difficulty that had appeared in the potential use of phenylthiocarbamide was that it was not taken very well by rats. A search began, therefore, for a close relative (chemically speaking) which had the same toxicity for the animal to be controlled and which would be accepted well enough to insure that normal feeding on baits containing the poison would kill. Du Pont's contributed most effectively in the chemical phases of this study. After many thiocarbamides had

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 16, 1946.

been synthesized and tested, it was found that alphanapthyl-thiocarbamide (or alphanapthylthiourea, as it is more commonly called) most nearly met all the requirements. Thus a new rodenticide was developed from a chance observation zealously pursued. Adequate testing, of course, remained as a later phase of the story.

An entirely different course of events led to the discovery of the rodenticidal value of "1080." Workers in a small laboratory of the U. S. Fish and Wildlife Service at Denver, Colorado, had been searching for many years for new rodenticides, a regular project in the program of improving control methods for noxious animals. As in prewar years, reasonably adequate supplies of strychnine, thallium, red squill, arsenic, zinc phosphide, barium carbonate, cyanides, carbondisulphide, and methyl bromide had given the rodent-control specialist a fairly wide choice of materials, the project for new rodenticides had received limited support—the actual need for new agents was not considered very acute. When the war changed all that, the Wildlife Research Laboratory applied to the Office of Scientific Research and Development for funds to enlarge the search for new poisons. Because of the interest displayed by the armed services, the enlarged program was approved and put into operation without delay.

To expedite this work, screening operations for the new compounds were begun at the Patuxent Research Refuge (U. S. Fish and Wildlife Service) near Washington, D. C. To Dr. Ray Treichler, chemist at the Patuxent, was assigned the responsibility of acquiring and testing all candidate materials. The aid of the major chemical companies in the country was solicited, and a large number of substances—whose toxicity was either known or suspected—were forwarded to the Patuxent. In addition to these contributed materials, a program of synthesis of certain series of chemicals was started, utilizing the staff of competent chemists working with Dr. Treichler. This system of operation continued for almost a year. Then Dr. Treichler arranged with Dr. Walter Kirner, one of the section heads in the National Defense Research Committee, to obtain samples of substances with which his agency had been working. Several highly toxic products were submitted for test, and one of these was "1080" (known chemically as sodium fluoroacetate), a material that had been studied by the chemical warfare agencies. A very limited test at Patuxent showed that to laboratory rats this compound was more toxic than any of the poisons in use. Extensive and careful trials were required to determine the practical utility of the material.

In the second routine phase of the program in the Fish and Wildlife Service project, all chemicals that had shown satisfactory toxicity in the screening tests at the Patuxent were forwarded to the Denver Laboratory for further examination under controlled conditions and for possible field study. Compound 1080 continued to show very promising results in the laboratory tests at Denver and so was ready for field trial.

In the experiments designed to determine the field utilities of these two materials a great difference in characteristics began to appear. Almost as soon as ANTU had passed its first laboratory tests at Baltimore, a sample was forwarded to Denver for comparative study. A portion of this sample was sent to Mr. H. J. Spencer, biologist and field investigator for the Wildlife Research Laboratory. Working at Gainesville, Florida, where he had available for his experiments the four species of wild rats known to exist in the United States, Mr. Spencer reported an interesting observation: ANTU would kill Norway rats at doses 20 or more times smaller than those needed to kill black or Alexandrine rats. Almost simultaneously, ANTU was sent to California, where another field observer, Mr. Joseph Keyes,

reported that the poison failed completely in its use against the California ground squirrel. These statements led to a complete study of the utility of ANTU, and the Fish and Wildlife Service reached the conclusion that the poison was useful primarily in the control of the Norway rat. In all of this work, certain other observations on ANTU were made. ANTU proved more toxic to mature rats than to young animals. It was found that a single sublethal dose would make a rat able to survive several killing doses in subsequent feedings. It was found that ANTU was somewhat dangerous to dogs, but that monkeys were quite resistant. The potential value of the poison was recognized in these trials and the Office of Scientific Research and Development made arrangements to give the substance widespread study.

Again, 1080 was different. Field trials were pushed to the limit of the ability of the Wildlife Research Laboratory, and the results of every test showed that 1080 had wider utility. The compound was effective on all species of rats; it was even more toxic to black than to Norway rats. It was one of the most effective substances ever tried on the California ground squirrel. It was exceptionally toxic to prairie dogs and to every other field rodent on which it was tested. On the other hand, this poison was highly dangerous to dogs and cats, and because it killed monkeys quite readily, its toxicity to humans was assumed to be rather high. A great deal of work on the possible treatment of accidental poisoning failed to disclose any effective antidotes.

With all of these facts in mind, the Office of Scientific Research and Development turned over to a Rodent Control Subcommittee the organization of widespread field studies with these two new rodenticides. The Rodent Control Subcommittee assumed problems of international cooperation and intensive studies with the armed services. In general, the reports confirmed earlier concepts, and interest in both materials increased by leaps and bounds. The use of ANTU in Norway rat control became established, and the methods with which it would give best results were determined. The U. S. Public Health Service undertook to modify the usual procedures to determine whether ANTU could be used in black rat control. For the simultaneous destruction of the rats and the fleas infesting them, there was devised a system of dusting rat runways with mixtures of this poison and D D T. Dr. Richter continued his laboratory studies and extended his program to include cooperation in a city-wide rat control project in Baltimore. Excellent results were reported in the use of ANTU. Favorable comments were received from England, New Zealand, and Australia, as well as from other remote areas where it was tried.

Compound 1080 was sent to England, Canada, India, Africa, the Hawaiian Islands, the Philippines, Okinawa, Australia, New Zealand, New Guinea, Alaska, and to many other countries in the western hemisphere. Reports have been very consistent, in that the poison is effective in controlling all forms of rats and other rodents, but that it is highly dangerous and should be used only by experienced and responsible personnel.

The hazards in the use of 1080, fortunately, are reduced to a certain extent when the substance is available only in the form of the finished bait. Its toxicity is so high for most of the animals against which it will be used, that very small amounts are needed to make effective poison formulas. For example, only 1 ounce of 1080 is used to prepare 100 pounds of ground squirrel bait; 2 ounces are needed to make 100 pounds of prairie dog bait; and 1 ounce will suffice to make 28 pounds of an effective Norway rat poison. Even at the highest concentration at which its use is recommended, ½ ounce will be enough to make 1 gallon of poisoned water.

When baits prepared with 1080 are compared with those made with some of the other common poisons, it appears that the danger to man himself is not so serious as might be expected. This is shown in the following tabulation:

COMPUTED COMPARATIVE TOXICITIES TO MAN OF SEVERAL COMMONLY USED RODENT BAITS

Poison	Highest concentration commonly used in bait	Estimated lethal dose of poison in mg/kg.	Amount of bait needed to kill a 150-lb. man
Arsenic trioxide	3% (1 part in 33 parts)	1.5-15 mg/kg	0.12-1.2 ozs.
Strychnine alkaloid	0.3% (1 part in 320 parts)	1.0 mg/kg	0.8 ounce
1080	0.4% (1 part in 256 parts)	5.0 mg/kg	3.15 ounces
Thallium sulphate	1.5% (1 part in 65 parts)	20.0 mg/kg	3.2 ounces
Zinc phosphide	2.0% (1 part in 50 parts)	40.0 mg/kg	4.9 ounces
Barium carbonate	20.0% (1 part in 5 parts)	800.0 mg/kg	9.9 ounces
ANTU	5.0% (1 part in 20 parts)	Unknown	Probably very large

It must be remembered, however, that the handling of the unmixed poison is an entirely different proposition. Compound 1080 is a light, fluffy white powder that is highly soluble in water and very readily absorbed. Men working with the powder should protect themselves against breathing the dust—and particularly against getting any into the mouth. The poison cannot be absorbed through the intact skin. It is to be hoped that only specialists who can handle poisons with the necessary care will be permitted to use the pure chemical.

Unfortunately, the figures in this tabulation give no indication of the comparative danger to pets. Compound 1080 is particularly hazardous to cats and dogs. These animals are susceptible to such small amounts of this poison that they are killed not only by eating baits prepared for rats, but also by feeding on the sick or dead rodents. This secondary poisoning characteristic of 1080 must be considered in every case where it is used; the poison must not be exposed where pets are able to reach the bait or to catch the poisoned rodents that may wander away from the baits.

Compound 1080 requires no particular method of use to make it effective; any of the attractive rat foods may be used with this poison. One ounce of 1080 will be enough to prepare 28 pounds of bait. The high solubility of 1080 in water, however, suggested the idea of trying it as the active ingredient in solution. Other toxic agents, such as sodium arsenite and thallium sulphate, have been in use for several years in various proprietary "poisoned waters," but distribution of the thallium products was discontinued during the war because of shortage of the poison, and the arsenic solutions have never been too satisfactory.

Mr. H. J. Spencer of the Wildlife Research Laboratory staff conceived the idea of using 1080, dissolved in water, as a complete rat and mouse bait. By careful experimental work he found that ½ ounce of 1080 could be dissolved in 1 gallon of water to prepare a most effective solution. His system of use was to expose this solution in ¾-ounce, waxed-paper, flat-type souffle cups. These were placed along rat runways and throughout infested areas. The addition of glycerine as an antifreeze agent has permitted winter use under a variety of conditions. It must be admitted, however, that though the present techniques have been most successful, there is a great deal to be learned about the most effective ways to use 1080; the ultimate value of the discovery of this agent cannot yet be estimated.

This report would be incomplete if no mention were made of similar work done in Germany during the war, in development of substitutes for thallium. Scientific teams that entered Germany with the invasion forces discovered that chemists in

that country had proposed two different chemicals as possible rodenticides and had installed manufacturing equipment to produce them. Chemically speaking, the first German substance is 2-chloro-4-dimethylamino-6-methylpyrimidine, and the second is p-dimethylaminobenzene diazosulphonic acid, sodium salt. As the first material seemed the most interesting, the Germans had given it the less complicated name of "Castrix." Preliminary tests on both of these substances were made in the United States, and it was found that both deserved more study. Accordingly, the Rodent Control Subcommittee requested that additional amounts be provided. This is being done through a contract issued by the Quartermaster Corps of the Army. As soon as it is possible to do so, extensive experiments will be undertaken to compare both German products with 1080 and ANTU. It is interesting to realize that wartime necessity forced searches for substitute poisons throughout the world.

In conclusion, it may be stated with certainty that the world now has more effective poisons than were available before the war. Four new materials have appeared, two in the United States, and two in Germany. Just how these chemicals will be used to best advantage remains to be determined. It is safe to state, however, that the judicious use of these new agents will aid in the continuing fight that man has been forced to wage against the noxious mammals which compete with him and his livestock for food, and which carry diseases to plague him.

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SANITATION ENGINEERING AND THE FOOD TECHNOLOGIST[1]

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The term Sanitation Engineering perhaps needs defining. Briefly, it is concerned with the essential sanitary details involved in the practical, aseptic processing of foods whereby their contamination by quality defective factors is not only avoided but brought under systematic and effective control. Stated another way, it is quality control brought into the focus of reduction to practice by scientific and technical means. Either way, it is easier said than done.

To begin with, if you insist upon being precise, we have in the term Sanitation Engineering an apparent contradiction of words for sanitation connotes a subject of considerable arbitrary judgment and opinion while engineering implies the factors of precision and exactitude so characteristic of the profession that follow its dictates. Yet such seeming inconsistency is not to be taken too seriously for in the application of sanitary engineering, we as food technologists are seeking to establish principles based upon sound practice.

Why the subject Sanitation Engineering and the Food Technologist? We have just stated that it is the mission of the food technologist to "establish principles based upon sound practice"—in other words, the philosophy of "technique not theory." We are, therefore, obligated to consider what particular functions the food technologist must consider as within his province in applying sanitation engineering. It requires a broadness of vision demanded of all technologists for we are specialists only in being food technologists—and right there any professional classification begins to broaden and encompass a variety of scientific, technical and practical applications.

It seems to us that Doctor Newton has boiled down the meaning of the word sanitation quite adequately and accordingly we quote:

"The word sanitation as applied to food carries a fairly definite meaning to each of us. Unfortunately, it does not mean exactly the same to any two people. There is even a wider divergence in the conception of the meaning of food sanitation when we compare ourselves with our grandparents. The conception of the word sanitation has, on the average, become more and more rigid in its meaning year by year until a period of one or two generations brings about a distinctly different meaning to the word and distinctly different ideas about how food processing should be carried out and food products maintained."

Those of us who have had occasion to be cognizant of the activities of our regulatory bodies (during recent years), such as the U. S. Food and Drug Administration, State Departments of Agriculture, as well as the various Departments of Health in states, counties, and municipalities, have come to realize that all of them are endeavoring to interpret that standard of sanitation which is most consistent with the prevailing public opinion. Because of the shades of differences which have prevailed at various times, and do even now prevail in different sections, we must recognize that standards of sanitation which were adequate at the beginning of this century are no longer acceptable and that those which are considered adequate today probably will not be satisfactory a decade hence just as those now acceptable in some sections are not acceptable in others even today.

Please pardon any reference to the dairy industry at this point. We do so because of an intimate familiarity with its sanitary practices over the past thirty

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years—practically a generation. In that span of time, it has been our experience to witness the development of sanitary practices whose progress have followed a fairly well defined pattern—a pattern that practically every food industry is now following or will follow. With the advent of pasteurization, the necessity for sanitary controls became evident. Remember pasteurization is essentially heat processing in degree. Milk being so readily subject to quality impairment and, incidentally, providing a vehicle of a very real potential health hazard, its sanitary control early became a matter of public welfare. With the evolution of improved methods and a correspondingly enhanced quality, milk required the respect and confidence of consumers before its markets were extended by increasing the quantities consumed. Truly, milk mirrors its quality in public health images. With the expansion of the factory system, and with the inclusion of other milk products in the dietary of the consuming public, sanitary control procedures and programs for dairy products became broader and at the same time more specific in their demands. Testimony of this can be found in the various revisions of the Standard Milk Ordinance of the U. S. Public Health Service. Market milk probably inherited many of its present-day standards from the activities of the certified milk producers which were adopted by progressive market milk distributors as the demand for improved quality in their products provided the incentive to raise their standards progressively. Ice cream, today, is following that pattern very closely as are the other dairy products now becoming engaged in similar programs—evaporated milk being one of the most recent to join the vanguard. And note this fact: evaporated milk is a heat processed food—not only in degree but in kind to many of our other heat processed foods of today.

Referring again to personal experience, it is not difficult to recall when sanitation in dairy practices meant primarily physically clean utensils and equipment only—or perhaps, we could have more correctly stated it as "primarily apparently clean utensils and equipment only." This correction is added because there was a time when prevailing standards of what constituted physical cleanliness did not recognize such a quality-defective factor as "milk-stone." To return to our narrative, the creamery divisions and, later, the cheese divisions of the dairy industry, due to the fact that the U. S. Food and Drug Administration was constantly revising its conceptions of what constituted proper sanitary standards, began to become conscious about ten years ago of a new terminology which was introduced in the polite phraseology of "extraneous material." That dignified polysyllabic expression has since gone with the wind and has now become instead the dread monosyllable "filth." Proving, of course, that while there are places in the world where certain insects are eaten and relished, the physical evidences of insect parts and vermin contamination detected in the extraneous material not normally considered a constituent part of any given food product is repulsive to practically all Americans and especially to all of the genus "inspectors."

If any further proof of the thesis that the sanitary practices of food industries are to follow the pattern established by the dairy industry is needed, it might be found in the statistics of the U. S. Public Health Service relative to "Disease Outbreaks Conveyed Through *Foods* Other Than Milk and Milk Products in the United States" when compared with the "Disease Outbreaks Conveyed Through Milk and Milk Products in the United States" for the year 1944 as reported by state and territorial health authorities. In the case of *foods other than milk and milk products,* there were 183 outbreaks of record whereas milk and milk products were accredited with 42 outbreaks of record. Obviously, the greater variety of *foods not milk and milk products* is legion and the great difference in the number of disease outbreaks

could readily be explained on that basis. However, we must not lose sight of the fact that milk and milk products generally constitute comparatively better vehicles for the transmission of disease than most other foods and, furthermore, milk is a more nearly universal food consumed by individuals of all ages. It must also be emphasized that the vast majority of disease outbreaks with *foods not milk and milk products* are attributable to failures in food handling which, incidentally, is also true of milk and milk products. To continue with these statistics, milk and milk products contributed to 10 outbreaks of record involving 303 cases of food poisoning, whereas *foods not milk and milk products* were found guilty in 155 outbreaks involving 4,503 cases of food poisoning (excluding botulism), all cases being investigated epidemiologically.

Thirteen outbreaks of gastroenteritis involving 305 cases were attributed to milk and milk products, whereas 90 outbreaks involving 2,883 cases were traced to *foods other than milk and milk products.* Furthermore, that old dread disease of typhoid fever in 1944 exacted its toll in 4 outbreaks involving 350 cases conveyed through milk and milk products, while other foods contributed 7 outbreaks involving a comparatively few 31 cases—again giving testimony to the unfortunately better vehicle it finds in milk and milk products. Dysentery was adjudged responsible for 3 outbreaks involving 42 cases traceable to milk and milk products, whereas other foods were found responsible for 3 outbreaks involving 677 cases. Let us repeat that all individual cases reported and of record were investigated epidemiologically. Also let it be reiterated that these statistics are no indictments of the performances of the food industries of America as the great majority of all these cases are traceable to failures in food handling. However, these figures are impressive in the fact that they do point to the tremendous strides the dairy industry has made in its public health record and that its pattern of sanitary practices and standards is one which all food industries can follow with profit.

In any discussion of sanitary engineering for the food industries, it appears that we have at least three major divisions to consider, namely: (1) pest and vermin control, (2) physical cleanliness of food contact surfaces, and (3) asepsis or the practical sterility of all food contact surfaces.

However, before beginning with a discussion of these three major divisions of sanitation engineering, it might be well from the engineering angle to consider briefly some over-all factors which involve food layout principles with emphasis on the sanitation problems. Leaving out for the moment, the important factors of construction design and architectural details, we might proceed with what in one man's opinion would constitute the highlights in planning the food plant of the future. Obviously, only a discussion of principles rather than details is possible in the time available. Then, too, inasmuch as a great variety of possible plant layouts could apply, no standard blueprint can be made. Even if such were possible, we promptly would find it impracticable because of the other factors involved in building site, surrounding barriers to expansion, terrain and a multitude of related real estate problems.

We will probably be safe in predicting that the food processing plant of the future will have to be designed with an eye to efficiency of operations and for very obvious reasons. Such a plant will tend to resolve itself, wherever possible, into a one-story structure with headrooms of varying heights depending upon the nature of the operations to be conducted within the structure.

Probably, the ideal location for the food plant of the future will be in the countryside within ready access of suppliers of the raw materials to be processed and, incidentally, where real estate values will permit expansions on a horizontal plane.

The orderly flow made possible in a one-story structure will be found of considerable importance in planning not only the economy of equipment placement but particularly in providing ready access for cleaning and sanitary practices. The latter is becoming increasingly important, both with respect to the essential labor required and to the facility with which inspection can be applied. A maze of pipelines and congestion of equipment is not only discouraging to the workers responsible for the cleanup, but has an important bearing on its effectiveness and economy. The cleanup tasks must be made as easy as possible to perform if effective results are to be assured. Then, too, congested conditions are always aggravating to the public health official whose peace of mind is such valuable good will to the management that it should not—in fact, must not—be ignored. Amen!

The principle of the one-story structure can be maintained as long as manufacturing operations are performed—or capable of being performed—on a horizontal plane. Supervision and labor conditions are better maintained when the same are under constant surveillance. While provisions for segregation of some departments and, incidentally, some operations are required for esthetic, economical or public health reasons, the single-story structure principle will usually be found much more advantageous than when multi-storied operations are used.

Single-storied construction will also provide for better and the most economical ventilation, an important consideration in processing operations where water and steam vapors can prove troublesome. Also, better natural lighting is provided. Space is fluid. Where buildings are properly located on their sites, expansions can take place when and where required without disintegration of established plant services and practices.

Consideration of a few construction details possibly will not be remiss. Floors should be properly sloped to an adequate drain system. In plants where appreciable volumes of water and liquid wastes are involved, a pitch of 3/16″ to the foot is often found convenient. Floors of smooth Handley brick 1¼″ x 4″ x 8″ are finding increasing favor over the old style packing house brick and cement floors with hard finishes such as terrazzo and other ground and polished surfaces. Brick is much to be desired particularly where considerable trucking or heavy utensil handling is involved as a badly chipped or opened spot can be readily replaced—and with a perfect seal. A smooth surface is highly desirable for quickly drying floors and for general sanitary reasons. Twelve by twelve-inch floor drain openings with four- to five-inch drain piping will always pay dividends unless inordinate amounts of waste liquids require increased facilities. Glazed tile for walls makes for neat appearances and ready cleaning. Placing of equipment should always include consideration of the location of floor drains in relation to points of origin of wastes as well as accessibility for cleaning purposes and the convenience of the employees involved.

The plant should be proofed against rodents with the elimination of false ceilings and other temporary wooden structures which provide breeding places for insects. Sugar and spice bins should have inclosed, rodent-proof storage space. Places for rats to get water to drink should be avoided. Proper screening to prevent entry of flying insects is essential both for sanitary reasons and the comfort of employees. Even sanitary motors and electrical receptacles are now being designed to eliminate breeding spots for crawling insects. A well-designed and properly constructed food plant will give due consideration to scrupulously clean and aseptic details, particularly in processing departments.

In the design of sanitary equipment, including sanitary piping and fittings, the Dairy Industry Committee, the U. S. Public Health Service, and the International Association of Milk Sanitarians have rendered singular service of interest and value to all food industries. Other groups are now active in establishing standards for sanitary equipment which will have the beneficial effect of minimizing conflicting public health requirements. Principles of design for sanitary construction are now widely desseminated and recognized by leading equipment manufacturers who have themselves contributed much to the advancement of sanitation engineering. However, whenever special equipment or newly developed apparatus, including food packages and containers, are on the drafting board, it is well to have the details checked by someone experienced in sanitary design so as to preclude later regulatorial headaches.

PEST CONTROL

From the viewpoint of damage to, or loss in market value of, foods, control over insect, vermin and rodent infestation demands major consideration. This importance attributed to pest control very likely results from the visible and material evidence of the presence of pests and the damage they do. Be that as it may, the problem of insect and vermin infestation is the most disturbing and ever-present threat to the peace of mind of the operating executives in every branch of our food industries. This managerial concern has been heightened by a decision of the U. S. Supreme Court (United States of America vs. Joseph H. Dotterweich—U. S. Supreme Court Reports, Law Edition, Vol. 88, p. 74, 1944) which holds that *"An officer of a corporation is subject to prosecution under the Food, Drug and Cosmetic Act for the acts of the corporation in shipping misbranded or adulterated goods though he may not have been conscious of the fraud."* Rather hard words but nonetheless unequivocal in character. This decision plainly means the presence of insect fragments, rodent hairs, and other debris is a definite legal liability just as is the accidental incorporation of poisons resulting from the use of toxic insecticides or similar materials. Therefore, every food technologist has the responsibility of ascertaining whether the pest control materials being used in any of his company's sanitary programs can comply with the requirement of being non-toxic and non-contaminating from a legal standpoint as well as non-tainting to any exposed food products in order to safeguard against unfavorable consumer reaction. In fact, the U. S. Supreme Court ruling just mentioned came about because of the accidental incorporation of a toxic insecticide in a food product.

It might be well to suggest that all pest control materials being used in a food plant be approved not only by a qualified entomologist but also that the toxicologist's or pharmaceutical chemist's expert opinion be included. This suggestion is offered because too many materials recommended for use by food industries have not been so sponsored. By way of illustration, the Supreme Court of Missouri in a ruling handed down December 6, 1943 (No. 38,581) granted a $20,000 injury claim to a man now dead from the use of an insecticide spray in which the lethal agent was identified chemically as Alpha naphthyl isothiocyanate. This chemical produced blisters on the skin and resulted in permanent kidney injuries later resulting in Bright's disease although as an insecticide it possessed a slow-killing action like D D T towards insects. It had been fortified with pyrethrum in order to make an effective fly spray. It is possible that this case may prove the basis for D D T injury claims later on.

Quite frankly, the knowledge of the toxicity of many of the synthetic insecticides towards humans and warm-blooded animals has not kept abreast of the knowledge

of their insecticidal effectiveness. Even certain base oils used in liquid sprays can be similarly investigated as evidence indicates all of them are not inert as sometimes detrimental reactions take place between the vehicle and the insecticidal agent. Perhaps it might prove of interest to quote excerpts from a report of a pharmaceutical chemist who acts as consultant to leading petroleum companies and insecticide manufacturers relative to some of the synthetic thiocyanates now being sold as contact insecticides:

"1. Thiocyanates

Group A—Alpha naphthyl isothiocyanate (This has just been discussed).

Group B—(1) N butyl carbitol thiocyanate, and (2) Beta thiocyanate laurate.

These insecticidal agents do not require pyrethrum for quick knock-down action.

They are toxic towards flies, mosquitoes, gnats and certain other pests but are not very toxic towards the roach family. These insecticidal chemicals are irritating towards the nose and throat in oil and water sprays. According to Dr. Harold H. Shepard's text book "The Chemistry and Toxicology of Insecticides" on page 303 will be found the following statements:

'Of rats exposed to n-butyl carbitol thiocyanate, eight out of ten died within 1¼ to 8 hours with one dose . . . It was found that liver tissue pulp can liberate hydrogen cyanide in considerable quantities from methyl and ethyl, much less from butyl and N-butyl thiocyanate.'

These quotations demand serious study.

Group C—(1) Secondary terpene alcohol thiocyanates, and (2) Fenchyl thiocyanoacetate.

This group of insecticidal agents does not require pyrethrum for quick knock-down action for the control of flies and similar insects.

They are not effective for the control of roaches or ticks. They are irritating towards the nose and throat when used in oil and water spray bases. This group of insecticides produced varying killing properties when used in different types of mineral oils. Our tests indicate that the aromatics and traces of catalyst in the mineral oils influences the stability and killing properties of these types of insecticides as well as other synthetic insecticidal agents."

Perhaps the best policy in the food industries regarding the use of insecticides and similar materials in food plants is to follow the Federal Specifications O-I-541a and O-I-546a. They are quite specific in stating that the insecticides *"shall not cause irritation to man nor be poisonous to man when applied in the usual manner in the destruction of common household insects."* Certainly the food industries should follow at least the specifications required for liquid household insecticides if only from similar considerations of safety. Or perhaps we might list our basic requirements as follows:

(1) Insecticides that are non-toxic to humans and warm-blooded animals.
(2) Insecticides that are non-contaminating—and non-tainting to any exposed food products.
(3) Insecticides free from incurring any legal liabilities through their use by non-technical workers or plant employees.
(4) Insecticides protected by adequate product liability insurance coverage.
(5) Insecticides free from fire hazards.

It might be noted in passing that the insecticides which will meet these requirements fully will, as far as present knowledge is concerned, include pyrethrum, rotenone and rotenoids. Ample and authentic scientific and pharmaceutical references will be found to justify their ready use. Other materials will no doubt be added from time to time but they should be required to meet at least the general specifications just mentioned. Perhaps food industries should study the matter and

initiate some official action for its own protection. After all, safety is fully as important as effectiveness—if not more so—in view of present legal liabilities.

There is urgent need for a technology which will minimize and eradicate insect and vermin infestations in order to be included, of course, in any adequate sanitation engineering program. The respiratory and leg paralysis of insects is not guaranteed by merely pointing an atomizing gun at the suspected points of infestation. Filling a room with a fog of the best possible insecticide will only kill the flying insects—the crawling variety safely harbored in cracks and crevices will not be disturbed in the slightest. However, where permanent spraying installations are desirable, the equipment must be designed to produce an atomization complete enough to prevent precipitation of the liquid insecticide. Special designed pneumatic atomizing nozzles with separate air and liquid inlets are greatly to be desired for best results. From the sanitation engineering standpoint, the important factors will include the effective concentrations of the insecticidal agents necessary to kill the various types of insects involved; an adequate air pressure as well as proper design of the spray gun to give lethal vaporization; and the frequency, method and points of application. A precaution worth mentioning is that steam cannot be successfully used for vaporizing a liquid insecticide if consistent results are to be obtained. Steam not only dilutes the lethal potency of the sprayed insecticide but in addition breaks down most organic insecticidal chemicals, particularly pyrethrum and rotenone.

While pyrethrum and rotenone are safe and effective insecticides when used in proper concentration, they do not destroy larvae or insect eggs. For that reason, spraying should be done at intervals of at least once a week during the actively breeding season. In the control of flying insects, daily applications may be necessary in which case the permanent type of spray equipment is convenient as it can be made to operate manually or by time clock.

We have mentioned only liquid insecticides. Powders generally are either effective but unsafe or safe and uneffective. Sodium fluoride is a good roach killer but, like the arsenates, is highly toxic and their use around food plants is to be avoided because of their possible poisoning effects. In fact, there are occasional instances where powders are mistaken for flour or similar food product ingredients. The U. S. Supreme Court has found this inexcusable as per their ruling recently discussed.

It would not be possible to discuss insecticides without mentioning that glamorous war baby—D D T. Although D. D. T. has had a romantic history, and has incidentally received wide and perhaps too enthusiastic publicity, there is every reason for food manufacturers to be extremely cautious in its use in a food plant. Knowledge of the toxicology of this interesting insecticide is confused although there are repeating accounts of serious poisoning of persons using it indiscriminately. In fact, its use in food plants is highly questionable. Leading insurance companies refuse to provide product liability coverage to insecticide manufacturers using D D T in their formulas. It is classed as an economic poison as is manifest by the caution labels being required for its sale to the public. An attitude of caution has been adopted by the U. S. Food and Drug Administration for the information of food manufacturers. In addition, there is growing evidence that its effectiveness upon certain insects common to food plants is either debatable or nil. For these reasons, and until more is known about it and its toxicology, food manufacturers should avoid any general use of D D T and particularly so in those operations where any possibilities of contamination of the food products being processed might be provided no matter how inadvertently. Better be safe than sorry.

In any discussion of pest control, fumigation cannot be ignored. This method is applied when the infestation is too extensive to be brought under control by more conventional and safe practices. Then, too, there are problems presented when the raw material being processed is itself heavily infested. Methyl bromide is being used rather extensively as a fumigant and a mixture of 75 percent ethylene dichloride and 25 percent carbon tetrachloride by volume is also of value as an industrial fumigant because its vapors are highly toxic to pests in all stages of their development; 1, 1-dichloro-1-nitroethane and acrylonitrile in combination with carbon tetrachloride also show promise of being useful. While it is not to be classed as a fumigant, the application of high frequency current through a dielectric field thereby inducing the necessary lethal effect by heat is successful in destroying insect pests in all stages of their development. Where a constant menace of heavy infestation exists as in old wooden structures, fumigation once or twice a year will be found profitable. In new plants, and often in the reconstruction of existing factories, study and application of proper construction detail will enhance insect and rodent control. Unfortunately, most fumigants which are used, including the cyanides, are just as lethal for man as they are for pests. Accordingly, they should be used and applied only with the utmost caution by an experienced operator whose instructions must be meticulously followed to avoid danger to both plant operatives and products alike. Fumigating chambers are often used in ridding raw materials of their infestations. Their operation also is a hazardous one which must be provided with elaborate and effective safety controls.

A very interesting and effective method of dispersing insecticidal chemicals was developed during the war by Dr. Lyle Goodhue in the Bureau of Entomology of the U. S. Department of Agriculture which is popularly known as the aerosol bomb. It is a container that holds the insecticide, dissolved in liquefied gas under pressure which upon release of the control valve disperses the insecticide into the air in the form of a fog or fine mist. Such atomizing effect is often referred to as fragmentation and is an extremely valuable feature in the contact poisoning of insects as the fine dispersion of the insecticide markedly increases its effectiveness particularly when compared with coarser distribution practices.

The production of insecticidal aerosols, according to Dr. P. N. Annand, chief of the U.S.D.A. Bureau of Entomology and Plant Quarantine is covered by patents assigned to the Secretary of Agriculture. Several firms have been licensed to use this invention and now that military requirements for large supplies of suitable insecticides and liquefied gas for producing insecticidal aerosols are reduced, some firms are offering the standard one-pound dispenser for sale. The license issued to them by the Department of Agriculture provides that they will produce insecticidal aerosols according to the standards prescribed by the U. S. Department of Agriculture.

Among a number of standard formulae that have been approved by the U. S. Department of Agriculture are those containing 3 percent D D T and a suitable amount of purified pyrethrum extract, which were adopted by the armed forces during the latter part of the war for killing different kinds of insects, especially flies and mosquitoes. The same formulae are now being used by most of the manufacturers operating under U.S.D.A. licenses and aerosol dispensers of the same efficiency are being sold to the public.

The aerosol bomb, however, is not too effective as a contact poison for crawling insects, especially roaches, which are not easily controlled by D D T in any solution and definitely not in as long concentration as the 3 percent specified for the aerosol

bomb. The one-pound dispensers now being distributed are not particularly practical for food plant use because they will not treat over 200,000 cubic feet, are not refillable, and are not effective against roaches and other insects indigenous to food plant operations.

Gammexene or 666 (Gamma-benzene-hexa-chloride) is an insecticidal agent developed and exploited in the wake of D D T with claims of being more effective and less toxic although Dr. Roland E. Slade, its early advocate, was apparently only vaguely informed as regards such particulars. Other authorities, however, have fairly well established its toxicity against certain species of insects which, if true, is many times more effective than pyrethrum or D D T, while Gammexene's toxicity to warm-blooded animals has not definitely been established. Apparently Gamma-benzene-hexa-chloride in tests upon warm-blooded animals has shown comparable toxic qualities to Dichloro-diphenyl-trichloroethan (D D T).

While insect infestation is something every food manufacturer abhors, there is nothing as repulsive, nor as expensive, as rodent infestation and pilfering. The Food and Drug Administration has many indictments against food processing plants for the presence of rat hairs in their products or merely for the evidence of any rodent contamination. To that end food inspectors are now being equipped with special ultra-violet ray lamps for detecting the soiling of sacks with mammalian urine as in such light it will give a characteristic blue-white fluorescence depending, of course, upon the natural color of fabric of the sack. This close policing by governmental agencies will become ever more stringent in the future from all present indications.

Four simple rules should be followed to control rodents:

1. Do not feed them.
2. Do not shelter them.
3. Deny them entry into occupied buildings.
4. Destroy them.

Feeding rats and mice is simply an indication of poor housekeeping and inadequate sanitary control within a plant. Sheltering them usually involves sloppy storage. Denying them entry into a plant requires simple rat proofing. Destroying them means either trapping, hunting, poisoning, or gassing them. A long list of potent killing agents is available with which experienced control experts are familiar. The two most recent additions consist of ANTU developed by Dr. Curt P. Richter of Johns Hopkins University, while 1080 is the material discovered by workers in the Wildlife Research Laboratory of the Fish and Wildlife Service. However, as far as food plants are concerned, red squill is the only agent which can meet the "non-toxicity" specifications. The new killers, ANTU and 1080, although more toxic to some species of rats than red squill, would be dangerous to use inside food plants.

The secret in killing rodents, however, does not lie only in the killing agent of the bait. The rat must first eat the bait. To acheive this, the bait, of course, must be attractive to the rodent. Enough red squill, if properly fortified, can always be included in a bait to kill rats, but the problem lies in making the bait palatable and attractive enough to get the rodents to eat it.

A recently developed rodent bait containing red squill has been given wide acceptance by those who have used it because of its strong attraction for rats and mice. Since rats and mice enjoy approximately the same diet as does man and, living in the dark as they do, they urgently desire foods, including vitamins, which are not easily attainable. This bait consists of many different food substances which fills

their dietary needs and in addition contains a strong biological and sexual attraction ingredient which has proven practically impossible for rodents to resist. These various components apparently overcome a desire for foods intended for human consumption. By thus catering to rodent preferences, it has been possible in this bait containing vitamin E in wheat germ oil and a series of other stimulating foods such as fish and vegetable oils, plus cereals, cheese, dehydrated meats and even dried blood to induce this pest to consume a lethal dosage of red squill.

Once a food plant has been freed of its pest infestations, it can be kept relatively free by effective control measures with safe and effective insecticides and rodenticides. However, it does require vigilant control practices and the proper training of responsible personnel to maintain satisfactory conditions and adequate sanitary control. Too much emphasis cannot be placed upon the importance of the properly trained personnel and the consistent application of effective control measurse. It truly is the responsibility of the management to provide such services within their own organization. Too much legal liability is involved to trust to the occasional application of control measures by commercial exterminators. However, if exterminator services are utilized, it is incumbent upon management to make certain that the materials and methods being used involve no legal responsibilities. Too often, this important consideration is lost sight of in an eagerness to be rid of problems that are repulsive and disagreeable, and particularly so when they assume extensive proportions. Prevention is the best practice and the most secure.

CLEANING PRACTICES

Cleaning and sanitizing operations of food-processing and handling equipment are the burden of every food plant operator. Too often they are relegated to the status of a "chore" with the admonition to "Let George do it." And, too often, George has tried to do the job with what he was supplied; a barrel or two of washing powder, a few brushes, maybe a scoop and a pail, but with no specific instructions or supervision.

It is often difficult to understand why a food manufacturer will spend freely of his time and money to learn about and to obtain the most effective and efficient type of equipment and methods for processing his product and then leave the cleaning of this equipment to an unskilled employee or at best rely on the recommendations of some enthusiastic salesman of supplies. Many a food plant is the experimental laboratory, and not too good a one at that, for the manufacturers of chemical detergents.

We all know that the treatment of boiler feed-waters is a highly developed operation and makes use of a technology which is profitable alike to the organization supplying the services and the products and to the concern utilizing them. No one with any experience in plant management would presume to debate the wisdom of boiler feed-water treatment. Yet, all too often the food manufacturer considers his boilers and neglects his processing equipment.

On the basis of ignorance or indifference, it appears that many managements might be relying on an alibi by permitting or accepting ineffective cleaning compounds to be used in its sanitary practices. Perhaps, the real reason is found in the failure to consider the physical cleaning of food-processing equipment and utensils as a chemical problem—disregrading their sanitizing for the moment. Actually, equipment cleaning is primarily and truly a chemical problem. In all cleaning practices, water is the common vehicle. It carries the cleaning agent or agents in soluble form. It is also the vehicle which must carry away the soiling substances

loosened and liberated by the detergency of the cleaning solution. Crystal clear and innocuous as it will invariably appear, the wash water used in cleaning food-processing equipment and utensils is never "pure" in a chemical sense as is distilled or de-ionized water, for example. The food-plant operator must be made to realize that his wash water is a complex chemical reagent that varies with its source and that sometimes varies even from the same source. It has to be considered before any intelligent use can be made of any detergent or cleaning agent which is another chemical or group of chemicals. In short, the food manufacturer must first know his water, then the type of soil to be removed and, finally, the detergent to be used if he is to have an effective cleaning solution.

He must, also, consider the possible effects of the water in rinsing the cleansed surface. Any staining or spotting characteristics it might show cannot always be disregarded because they can provide the starting point of truly serious deposits such as water-stone deposits or even corrosive attack on metal-plates used in containers, for example. Incidentally, distilled or de-ionized water can prove particularly troublesome in the latter respect. Water treatment for cleaning and rinsing purposes requires the application of a high order of technology. Thus sanitation engineering must assume its full responsibilities in any effective and practical sanitary program.

Evidence that progress is being made in detergent technology is found in the increasing use of wetting- or surface-active agents and the polyphosphate salts. To consider the latter first, they are being used in detergent compositions to reduce the dissipating effects of "hard waters" by minimizing precipitation of hardness imparting constituents of the wash water as well as preventing staining or spotting due to the formation of adherent films of calcium and/or magnesium salts. They are also effective in minimizing rusting effects. However, it must be kept in mind that polyphosphates vary in their properties and that streaking types of stains appear when a deficiency of polyphosphate is used. Then, too, the polyphosphates vary in their stability to heat. Also, in discussing polyphosphates, it must be remembered that any of them above sodium tripolyphosphate, for example, are in the nature of glasses and a precise chemical formula is a practical impossibility. As a matter of fact, in manufacturing polyphosphates those skilled in the art are guided more by the ratio of $Na_2O : P_2O_5$ in making the glasses than in attempting any precise chemical formulation. This must be kept in mind in specifying such chemicals. Thus, the source of supply becomes very important.

Wetting- or surface-active agents have come into increasing favor in food plant detergency although they vary widely in their properties both as regards their cleaning effectiveness and their compatibility with other cleaning agents in aqueous solution. Many of them create problems when used in hard waters. Too often their foaming ability is the criterion by which their effectiveness is judged—and with very unsatisfactory results. They also vary in their tendencies to cause skin eruptions upon the hands and other exposed parts of the body coming into repeated contact with their continued use in cleaning practice. We are still in our infancy when it comes to any substantial knowledge concerning the use of wetting agents in detergency although their effectiveness cannot be ignored.

Truly, there are many straws in the wind of detergent technology. We must always keep in mind that cleaning compositions which are specific for certain waters are not necessarily applicable to all types of waters used as their solvents or vehicles. Furthermore, the type of soil to be washed and rinsed away, the character of the

equipment or utensils surface to be cleaned, the staining characteristics which appear only after repeated washings and rinsings, the dissipating influences of certain chemicals upon the detergent powers of certain other essential chemicals are among some of the more important factors to be considered in the development of effective detergents. Too many ready-made products are being offered for use in applications where a tailor-made item is necessary. And in the final analysis, all the various properties of detergents are either enhanced, dissipated, or unaffected by the chemical character of the wash water which is their vehicle.

Intelligent surveys and enlightened analysis of quality control problems are essential to the development of a sanitation engineering technology which will be the tool of every food technologist, every sanitarian, and every governmental regulatory official as well as every food plant production manager. A working sanitary program will involve more than mere water analyses, making of surveys, working out specifications and the like. It involves also that very important and vital obligation to teach cleaning practices to the directors of research and production development departments, as well as to the operatives and employees of the processing and production departments.

The development of an effective detergent technology is truly a challenge to the ingenuity of all food technologists. Some of the principles of chemical engineering are inherent in some of the food industries' cleaning problems, particularly where automatic cleaning devices and equipment are involved. In other words, detergents and their applications are crying aloud for the leadership that can come from well-established principles in sanitation engineering.

SANITIZING (ASEPSIS)

Asepsis is always the ultimate step in the attainment of sanitation as far as food-contact surfaces are concerned. Such practice is, of course, essentially precautionary and of the nature of an insurance policy to prevent contamination of the cleansed surface prior to their use or to coming into contact with the food product subsequently processed.

As long as chlorine is the essential bactericidal chemical, an exercise of judgment is possible by buying it on the basis of its ability to destroy microorganisms. That basis of purchase resolves itself simply into obtaining the maximum amount of chlorine at a minimum cost. However, present indications are that the future possibilities may change such simplicity of procurement and application because many compounds are being developed which will prove highly competitive to chlorine—once they become available.

Chlorine in its most available form is an oxidizing agent; in fact, its ability to corrode metals and to sterilize them is due to this characteristic. When it is used in organic forms such as chloramine T or chloramine B, it is more stable than most hypochlorites. The speed with which the available chlorine is liberated from the chloramine forms or the hypochlorites is dependent upon the reaction (pH) of the solution. In an alkaline reaction all of the so-called available chlorine is not readily available; yet it is released rapidly when the solution is made acid. Incidentally, with the proper reaction (pH) of the solution, a few parts per million of available chlorine will do the work of many parts otherwise. In fact, the sterilizing action of chlorine germicides is apparently determined by: (1) the reaction (acid or alkaline) of the solution in which it is used, (2) the amount of organic matter in the water in which it is dissolved or suspended, (3) the temperature of the solution, (4) the

length of time the solution is allowed to act in contact with the surface to be sterilized as well as (5) the degree of penetration which it can affect.

Many of the high-test hypochlorites have heretofore been available in insoluble forms which have required considerable handling and preparation on the part of the user. A soluble lithium hypochlorite of extremely high available chlorine content eliminates many of these disadvantages and may become available at a practical cost as the supply and demand increases.

With the development of many new chemical compounds because of war needs and material shortages, one can expect them to be put on the market within the not too distant future. Synthetic detergents and the development of cationic and anionic wetting agents with germicidal and bacteriostatic properties is opening new fields of application, not only in asepsis but in detergency as well. However, these so-called detergent-sanitizers should be used with caution because many have been found to be deficient—both as detergents and as sanitizers. There are several cationic compounds which, when mixed with certain detergents, offer marked possibilities as detergent-sanitizers but have limited practical applications. Use of the much publicized penicillin appears to be confined to its medical applications where it is effective as an antibiotic agent. Chlorellin, a new member of the penicillin family of bacterial-inhibiting compounds, is an unusual germicidal agent in that it synthesizes its food out of natural raw materials. However, much research and development is necessary before the importance of these antibiotic agents in sanitary practice can be properly evaluated.

Certain quaternary ammonium derivatives have been advocated for use as sanitizers in food plants. Among these, alkyl dimethyl benzyl ammonium chloride (known commercially as Roccal) and certain fatty acid esters of colamino formyl methyl pyridinum chloride (known commercially as Emulsept) have attracted the serious attention of health authorities. Because the conventional phenol coefficient method of evaluating germicidal power sometimes gives widely divergent and deceptive results, the effectiveness of these ammonium derivatives has not been fully evaluated. There are many obvious advantages to be claimed for such compounds but food plant operators can justifiably be conservative in using them until more definite knowledge is available concerning their performances under practical conditions.

Until this newer knowledge of sanitizers is more fully determined and understood, hypochlorites and chloramines will probably continue to be used widely. Their utility will be greatly increased when advantage is taken of supplementary conditions which will make their maximum germicidal action possible. In the food industries, new products are forced to run the gamut of exhaustive testing before they can be widely used. Otherwise, an unknown toxicity or any poorly understood conditions of application might result in unfortunate and costly circumstances.

The important consideration to keep in mind is the urgent need for a technology of sanitizers similar to that needed for pest control and detergency. Only in that way can their various merits and limitations be fully evaluated and understood. A basic principle in food plant sanitation is that physical and chemical cleanliness is a necessary prerequisite to any form of asepsis. It is a principle which must be strictly followed. The groping for detergent-sanitizers can result in dangerous philosophies and can undo much of the present gains attained in sound sanitation engineering practice. We, as food technologists, have quite different problems than medical practitioners in whose hands detergent-sanitizers have remarkable properties of cure and healing. *Ours is the basic problem of prevention—not cure.*

Again, we plead that sanitation engineering be required to provide the basic principles so that understanding and practice be consistent with technical knowledge and not in the happen-stance of habit and assumption. In other words, sanitation engineering and the food technologist should ever advance "technique, not theory." That is our greatest task—and our greatest opportunity.

DISCUSSION OF THEORY OF MOLECULAR INTERACTION IN PROTEINS AND POSSIBLE APPLICATIONS IN FOOD TECHNOLOGY[1]

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INTRODUCTION

We are familiar with what happens when an egg is placed in boiling water; the content turns solid, changes color, and develops a characteristic odor. Yet when asked to define the chemical and structural changes that have occurred in the egg we are faced with a most difficult situation. We are not satisfied with the answer, "It has coagulated."

Foods are commonly subjected to heat, to cold, to mechanical, osmotic and gaseous pressures, to visible and ultraviolet radiation, to desiccation, to surface forces, to agitation and to grinding. All of these physical forces can affect the quality of foods, favorably and unfavorably, by changing their nutritive value, digestibility, storage and shelf life, appearance, solubility, and their texture. We ask, "How?"

Changes of this sort are the manifestation of molecular changes—changes in the chemical and structural properties of the proteins, carbohydrates, and fats, and in the large molecular aggregates involving two or more species of these molecules. The mechanisms of these changes are complex and are far from being completely understood, yet certain fundamental facts have been established.

This discussion is concerned with a few of the recognized aspects of the structural response of proteins towards physical forces. It is possible that increasing knowledge of these characteristics will lead to a better understanding, in general, of the effect of physical forces on foods.

It has been said, and perhaps rightfully, that "we are what we eat." Even literally speaking when we consider proteins, this remark is not so far afield. For in the cytoplasm and nucleus, proteins form the basic constituents of all living cells; as muscles, proteins are responsible for the contractions that enable us to move; as brain tissue and nerves, proteins perform our highest mental and control processes; as tissues of our eyes, proteins enable us to see; as skin and hair, they cover and protect us; as gastric and intestinal enzymes, they digest our foods; and as egg white proteins, aside from their embryological significance, they are one of our most important foods. This discussion shall be limited to the proteins of egg white whose behaviors are perhaps better known than those of many other proteins.

NATURAL CHAIN STRUCTURE OF PROTEINS

About 70% of the solids of egg white is so-called albumin protein and 1/10 of this or about 7% is a mixture of another type, called globulin. The insoluble coagulum that forms when we boil an egg consists of these proteins congealed as the result of transformations in their molecular structure. Let us examine this change more closely.

Proteins have been said to possess the "hallmark of individuality." Fundamental studies indicate that protein molecules are chains of atoms built by the end-to-end

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[1] Presented at the 7th annual meeting of the Northern California Section, Institute of Food Technologists, Berkeley, California, December 6, 1945.

[2] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

combination of several hundred molecules of 20 to 30 relatively simple amino acids. A schematic chain made up of 13 of the amino acids is illustrated in Fig. 1. The proportion of individual amino acids comprising different proteins varies considerably; slight differences in composition are even found in corresponding proteins from eggs of different species of birds. The albumin of duck eggs, for example, differs somewhat in composition from the albumin of hen's eggs. Nevertheless all proteins have similar structural properties. As shown in this figure, one is a backbone structure of connected carbon and nitrogen atoms, and another is the presence of groups of atoms called side chains, located laterally like arms and legs along the backbone chain. The behavior of proteins towards physical forces depends on the behavior of the backbone and the attached appendages.

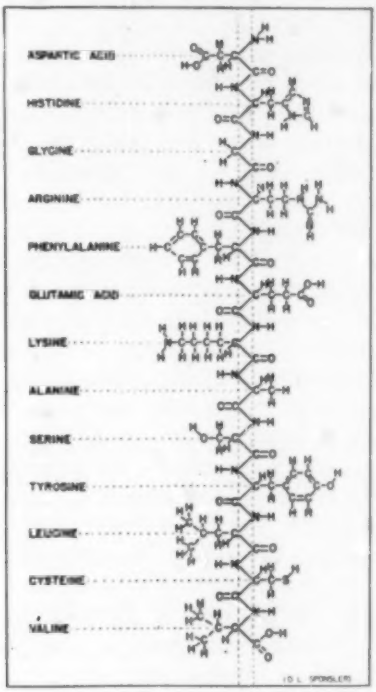

FIG. 1. A schematic protein chain built from 13 of the 20 to 30 known amino acids. Natural proteins contain as many as several hundred of the amino acids combined as shown. Attached to the backbone of repeating carbon, carbon, nitrogen atoms are the side chains on which are chemical groupings which may become charged and thus capable of interaction with other charged groups. The extent and force of such interaction determines the stability of proteins.

The backbone consists of a repeating combination of 2 carbon atoms and one nitrogen atom and has a side group attached on one of each pair of carbons all the way along the chain. Because all of these atoms are connected by single chemical bonds they can rotate around these bonds as axes, and the result is a chain which as a whole is flexible and, depending on the influence, can undergo various contortions.

CURLING AND UNCURLING OF PROTEIN CHAINS

Curling and uncurling of chains is fundamental to the behavior of proteins; it is responsible, for example, for the changes observed when egg white is heated or when it is whipped into a foam. This curling and uncurling of protein chains is responsible for the elastic properties of sponge cake, angel food and of meat and bread. But

this behavior is not limited to the proteins of food; it accounts for the unique properties of wool and silk; neither is it limited solely to proteins, for similar characteristics are responsible for the elastic properties of rubber and of nylon.

Rubber and nylon can be regarded as prototypes for the study of proteins. In rubber we find long chains, but these are entirely different chemically from the protein chains of muscle fibers, flour dough, wool, silk, or egg white. Rubber chains are composed entirely of connected carbon atoms having only small so-called methyl groups as side chains. Nylon is composed of chains of connected carbon and nitrogen atoms similar, somewhat, to the chains of proteins. X-ray analysis of rubber and nylon shows both to have a fibrous structure in the stretched state, in which the long chains are aligned in the direction of the stretch. In the unstretched state rubber and nylon have a seemingly random structure—the chains are crumpled in a "brush-heap" fashion.

The proteins, similarly, show fibrous structure when their chains are stretched out by physical forces. However, the chains in the native proteins of the egg white type, unlike the chains of unstretched rubber and nylon, are uniquely folded as small packets or corpuscles of uniform size. But when the chains have been displaced from this uniquely folded state, or as we say, "denatured," the probability of their return to this configuration, when the displacing force is released, is exceedingly small; we find that they now crinkle like the rubber or nylon chains into a random arrangement. Evidence of this behavior is obtained through various physical measurements, such as diffusion, viscosity, and surface film studies. Such measurements, for example, indicate that the neatly folded corpuscular egg albumin is shaped roughly as an egg. If we select one 10 millionth of an inch as a unit of length then we may describe the egg albumin molecule as about 3½ units long and 1½ units wide. These dimensions change profoundly under influence of certain physical forces. For instance, when a small amount of a solution containing corpuscular native egg albumin is layered on the surface of water the tension forces in the water surface overcome the internal forces holding the protein chains in the corpuscular state; the chains unfold and become stretched out on the water surface. Optical measurements show that the film of protein that forms is now only ⅜ of a unit thick instead of 1½ as in the original protein, and corresponds to the cross sectional width of a single stretched-out protein chain. Further calculations show that the length of the stretched-out chain is 42 to 56 units compared with the length of three or four units, of the original protein.

Uncurling by surface forces is common. For example, it occurs when solutions containing proteins are subjected to agitation which causes the protein to accumulate in the resulting foam. The protein chains in egg white that is beaten stiff uncurl in the small bubbles and they remain stretched out as long as the surface forces are acting, but when the bubbles collapse the chains spontaneously crumple, this time, like the chains in rubber, into an irregularly snarled arrangement. The protein as a result changes in solubility, in texture and in other physical properties.

THEORETICAL BASIS FOR CHAIN BEHAVIOR

The spontaneous crumpling of long chains or free portions of long chains is responsible for the "snap" in rubber, in bread dough, and also for muscle contraction. This tendency is due to a "fundamental desire of molecules to increase their elbow room." Physical chemists and engineers prefer a more formidable expression—"increase their entropy." We are acquainted with this behavior in another way. The molecules of a gas, for example, are in continual kinetic motion. When confined, the gas molecules seek to escape and to diffuse. The pressure exerted by a

gas is manifestation of this continual molecular commotion. In the upper half of Fig. 2 we represent gas molecules confined in two cylinders. In the left cylinder the escaping tendency of the gas is shown balanced by a small external pressure. In the right cylinder the gas is shown further compressed; the greater escaping tendency is shown balanced by a greater external pressure.

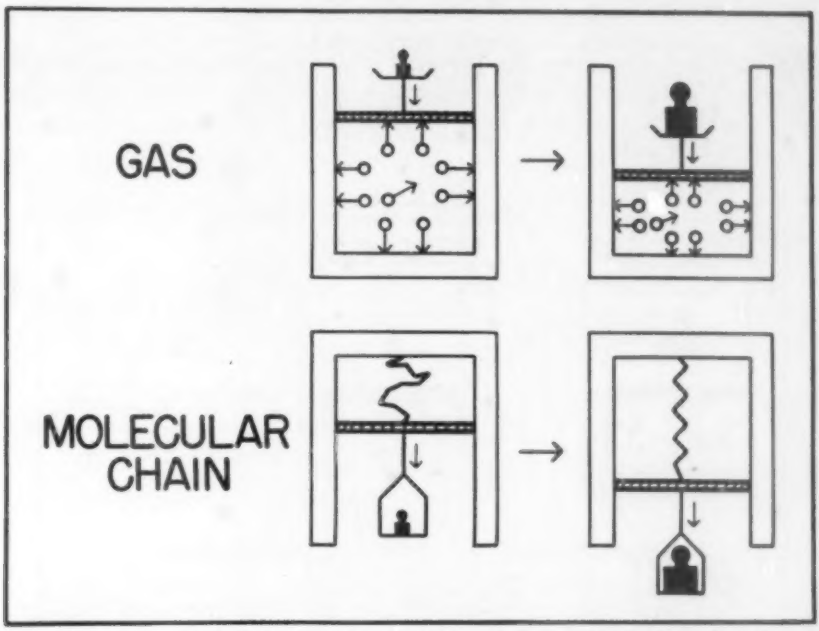

FIG. 2. Comparison of the behavior of long chain molecules with the behavior of gases. The molecules of a gas are in continual thermal motion which accounts for the pressure of a gas when it is confined. The gas seeks to escape from confinement and if the temperature is raised this tendency is increased because of the increased thermal activity. Chain molecules, similarly, undergo constant thermal movement, but because the atoms comprising the chain are connected, the chain motion is limited to a sort of whipping. The diagrams attempt to show these molecular motions as counterbalanced by externally applied forces. When a gas is compressed or when a chain is stretched (that is, when the molecular motions are restricted) a greater force is required to prevent them from increasing their "lebensraum."

Chain molecules, similarly, undergo constant kinetic movement, the rate, as in gas, depending on the temperature. Because the atoms of the chains are connected their motions are necessarily limited to what we might call a sort of whipping movement. They can undergo maximum displacement when the chains are relaxed and minimum displacement when the chains are stretched out. In the lower half of this figure the diagram at the left illustrates, analogous to the case for the gas, the crumpled-up chain in equilibrium with a small external force. The center of the chain, in this case, is free to whip about in various directions. To the right the range of vibration is shown restricted by stretching. Here, just as in the compressed gas, external energy is required to balance the tendency to contract. When the external force is removed the stretched-out chain spontaneously snaps back into its relaxed state where the free portion can move freely with maximum elbow room.

Sometimes, as in drawn nylon or as in permanent waves, the constituent chains do not relax; they are prevented from relaxing by attractive forces more powerful than the kinetic force of contraction. Attractions set up between several chains or portions of chains hold them together in bundles and prevent relaxation.

Before considering the attractive forces operating between protein chains it will be instructive to carry our analogy with gases a little further. Ideal gases, we recall, are those in which no mutual interaction occurs between the separate molecules. In other words, the escaping tendency, *i.e.*, the pressure of such a gas, when confined as shown to the left in Fig. 3, depends solely on the temperature, according to the well known law $P = \frac{RT}{V}$. Only a few gases approach ideal behavior; in most of them, the so-called real gases, the pressure is decreased by the attractions between the molecules. This intermolecular attraction, or in other words, reduced escaping tendency, if powerful enough, will cause condensation of the gas to a liquid and the liquid, in turn, to a solid.

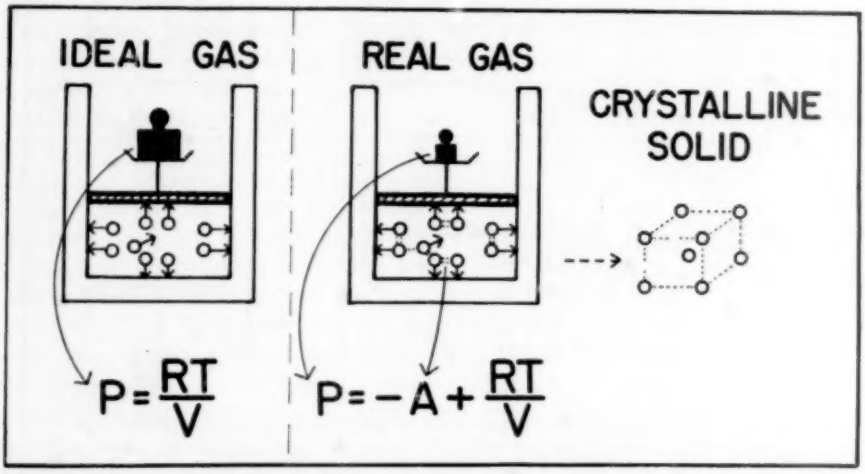

FIG. 3. Comparison of an ideal with a real gas. With no attractive forces operating between the molecules of an ideal gas its pressure, when confined, is determined solely by the temperature, T.* In the real gas, on the other hand, where attractive forces exist, the pressure is lessened by the extent of the interactions, designated for convenience, by a negative A. Should the attractive forces become sufficiently great a new state of order among the molecules may arise when the gas condenses to a liquid. With further interaction the molecules of a liquid may freeze to a solid. The crystalline state represents the highest order.

* The equation $P = \frac{RT}{V}$ is the ideal gas law, usually written $PV = RT$. In this equation T represents the temperature, V, the volume, and R is a constant. So if the volume of a confined gas is held constant the pressure, then, depends only on the temperature.

As shown in the diagram to the right, intermolecular attraction can be expressed in a simple way mathematically by the introduction of the term A into the expression for the behavior of gases. Thus: $P = -A + \frac{RT}{V}$. A is negative in sign, indicating that internal molecular interaction reduces the pressure. The transition of a gas to a liquid or of a liquid to a solid is manifestation of increasing mutual interaction among molecules. The transition represents an increase of order among the molecules which becomes highest when the solid crystalline state is reached. When the attractive forces favoring crystal formation in a given environment are strong enough the material remains stable in that environment, but when a solvent or heat overcomes the internal molecular attraction, the order is lost. A crystal of sugar, for example, will dissolve in water because water has greater attraction for the

sugar molecules than the sugar molecules have for themselves. Also a crystal of iodine sublimes to gaseous iodine on heating because the thermal dispersive forces overcome the crystal lattice attractive forces.

Fig. 4 illustrates the result of mutual interaction between long chains. In the diagram on the left several chains are shown having no interaction. They are shown stretched out by a particular force. To the right and for comparison several chains are shown which have interacted over certain areas with the result that less force is required to extend the *remaining free* chain segments. The interacted areas do not relax. As we say for drawn nylon or permanent waves, they have become set. Just as in real gases, the mutual interaction among chains can be expressed mathematically by the introduction of a negative A in the relation expressing the force as a function of the temperature.

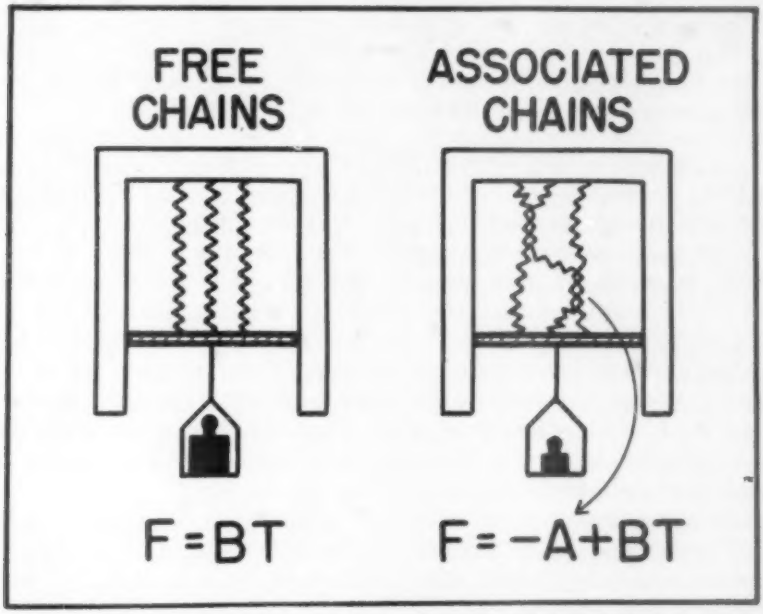

FIG. 4. Comparison of the behavior of free with interacted (associated) long chain molecules. Analogous to the behavior of ideal and real gases, the force required to extend chain molecules depends on the temperature and on the extent of chain interaction. The force required to extend free chains, as illustrated by the diagram on the left, is determined, as is the pressure of an ideal gas, by the temperature alone. But where portions of the chains have interacted, as illustrated in the diagram to the right, the force to extend the remaining free chain segments is decreased by the extent of interaction, A.

ORDER AND STABILITY AMONG PROTEIN CHAINS

Now to come back again to proteins, we find a similar situation. We stated that the chains comprising the proteins of native egg white are held confined in a uniquely folded state. This state of order is maintained by attractive forces having their origin in the charged centers located on the side chains along the backbone structure. The chemical attractions between these charged centers result in holding the separate chains folded into corpuscles as in egg white proteins or in holding several chains together in network structure, as in feathers, wool, and muscles.

The native order is lost when the egg white is heated. The thermal energy overcomes the chemical attractive forces whereby the highly regular moelcular pattern

disappears. The chains freed in this way from their corpuscular confinements then interact in a scrambled fashion and, presumably, with greater force to give the coagulation observed when the egg is boiled.

MOLECULAR ORDER AND NUTRITIVE VALUE OF PROTEINS

From these interpretations we may proceed to another aspect of protein behavior—that of their nutritive value. Contrary to popular opinion the nutritive value of egg white is greatly improved after the proteins have been coagulated by heating. The coagulated protein is more readily digested by enzymes. Even in the test tube coagulated egg albumin is more readily attacked by trypsin than is native egg albumin. It is believed that the large enzyme molecule, also a native corpuscular protein, is not able to approach the charged centers in the native structure, but once the chains are in random configuration, when these charged groups are exposed, then the protein becomes subject to attack by the enzyme. This effect of increase in digestibility of proteins on heating is common. We know for example, that the proteins of navy beans, lima beans, and soybeans are outstanding in their low nutritive value because of indigestibility, but after heating for a short time in the presence of moisture, they become readily digestible.*

MOLECULAR ORDER AND PROTEIN-WATER RELATIONSHIPS

This leads to another point of interest particularly recognized in regard to the processing and storage of foods, namely, the profound influence of water on the stability of proteins. If the water content of egg white is reduced we find that the temperature at which coagulation of the proteins first occurs is correspondingly increased. Thus where ordinary egg white begins to coagulate around 60° Centigrade, egg white containing only 6% water coagulates around 145° and when the water content is reduced to less than ½% coagulation does not occur at 160°. This effect of dehydration on increase in temperature of coagulation is also evident when sugar is added to ordinary egg white. The presence of sugar raises the temperature of coagulation, because it competes with the protein for the water, and so in effect tends to dehydrate the protein.

The water in a protein water mixture is attracted by the charged centers of the protein. The water tends, as a result, to overcome the mutual attraction between the folded chains, analogously to the effect, which we have described, of water in dissolving a crystal of sugar. As the water content of a protein-water mixture is reduced, whether directly by drying or indirectly by the addition of sugar, the mutual interaction between the chain segments increases, with the result that greater thermal energy, or in other words a higher temperature, is required for changing the state of order in the protein. These aspects have definite application in the storage of protein materials.

There is another observation of interest in the preparation of foods that we obtain from coagulating egg white. It illustrates the change in molecular attractions and their relation to water. When egg white first coagulates it is jelly-like, for it still contains much water. As the cooking continues, more and more of the charged centers in the protein interact and water is expelled with the result that the coagulum shrinks and becomes rubber-like. We are familiar with this behavior in scrambled eggs or baked custard, which become firm as they are cooked but which are watery if the cooking is carried out too quickly or too long. There is much yet to learn

* With soybean protein, there is, in addition to the increase in digestibility due to these physical changes, a greater increase in nutritive value due to complex chemical changes that take place in the protein on heating.

concerning the relation of water to protein stability. Various aspects of this vast subject, constantly met with in food research, are under investigation at the Western Regional Laboratory.

UTILIZATION OF SURPLUS AND INEDIBLE PROTEINS

An additional point in regard to protein structural behavior can be illustrated again with the coagulated egg white as an example. Reference was made to rubber-like coagulated egg white and to relaxation of the constituent chains into a random and brush-heap state; if a force is applied to stretch the coagulum the chains untangle, straighten out, and, like nylon, they may become permanently set through mutual interaction in this aligned condition; we say then that we have the protein in the fibrous state. This, essentially, is the principle employed in the making of synthetic fibers from various surplus or inedible proteins. The new state of order set up artificially among protein chains in synthetic fibers is similar to that in the natural protein fibers and fibrous materials (wool, muscle, silk) and accounts for desirable mechanical qualities found in these materials.

CONCLUSIONS

To summarize, we may say that order in proteins, or for that matter, order in any material, as well as stability of any system is determined by the extent of mutual interaction between the constituent molecular units.

We may go even further and say that mutual interaction among molecular units determines the physical properties of all materials—their solubility, their texture, and their hardness—and, of greatest importance to food technology, the keeping quality of foods.

Keeping quality is intimately tied up with the stability of numerous constituent molecular units. Though this discussion has been limited to the behavior and stability of proteins, there is also the behavior of protein combinations with other molecular species, of wide occurrence in foods, to be considered.

Besides their interaction with water, proteins undergo combination with carbohydrates, with lipids, with vitamins, and with a host of other molecules present in foods. Physical forces which operate on foods, which we have discussed for the egg proteins alone, will change the extent of mutual interaction among the various constituents, however small the quantity present, and these changes, in turn, may lead to subtle chemical reactions in which there is development of off-odor, off-color, changed solubility and changed flavor.

In this perhaps overly simplified version of the theory of the molecular interactions in one of the most complex systems which compose foods, we have sought to point out how fundamental studies may lead to a better understanding of what makes food fit to eat, why it becomes *unfit* to eat, and what, if anything, can be done about it. Such an understanding may also lead, eventually, to an inkling of why "we are what we eat."

PRE-STERILIZATION OF CANNED TOMATO JUICE [1]

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INTRODUCTION

The term "pre-sterilization" has been chosen to designate a method of canning tomato juice and tomato juice cocktail (pH below 4.5) which employs a high-short process during flow through a heat exchange system prior to filling into cans.

This procedure has been developed to provide a means of destroying acid-tolerant, heat-resistant spoilage organisms which cannot be destroyed by conventional processes without a severe quality loss in the product. This accomplishment is dependent upon two principles:

1. The increase in rate of heat penetration effected in a tubular or plate type exchanger decreases the processing time at a given temperature below that required for conventional methods of processing in the can.
2. The use of a high processing temperature reduces the degree of chemical change in the product for a given severity of bactericidal effect, when the high temperature process is used in conjunction with rapid heating.

Although tomato juice appears to be a thin liquid, heat penetration tests indicate that when it is processed in cans without agitation the heat transfer usually is entirely by conduction. Consequently, the length of process required to destroy heat resistant organisms even at temperatures above 212° F. is such that it has a definite deleterious effect on the juice.

Tomato juice cocktail is a mixture of juices of various non-acid vegetables and tomato juice in such proportions that the resultant mixture has a pH below 4.5. Since the processing requirements for this product are similar to those for tomato juice, the two are considered together here.

HISTORICAL REVIEW

During the decade 1930 to 1940 canners reported a number of instances of spoilage in tomato juice and tomato juice cocktail and theoretical concepts regarding the heat treatment required to sterilize tomato juice had to be constantly modified by commercial experience. In the late twenties when this product was first canned, it was thought that since tomato juice is an acid product with a pH below 4.5, it could be sterilized by filling at 190° F., inverting the closed cans and cooling. As the volume of production increased in the early thirties, more and more spoilage troubles were encountered due to acid and heat tolerant microorganisms. Berry (1933) isolated such an organism, which he named *B. thermoacidurans*. This organism was found to have a heat resistance in tomato juice in excess of 90 minutes at 212° F. and was isolated as the causative agent in severe flat sour spoilage losses. The spoiled product manifested a normal vacuum. Hence, there was no means of detecting the spoilage by external observation of the can. The pH values were also often within the normal range. The off-flavor increased in intensity over a period of time. At first it was merely unappetizing; later it became bitter, then slightly sour, finally quite unpalatable.

Townsend (1939) found a group of bacteria, acid-producing, spore-forming anaerobes closely allied to *Cl. pasteurianum*, causing swelled can spoilage in tomatoes and tomato juice. The heat resistance of this organism was such that heating times of 8 to 20 minutes at 212° F. were required for destruction in tomato juice in thermal

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 16, 1946.

death time tubes when the number of spores per tube was varied from 20,000 to considerably over 100,000. The processes that were used in 1939 for tomato juice were inadequate to destroy high concentrations of this organism and consequently spoilage was experienced.

As a result of a number of plant surveys, Cameron (1935 and 1936), Pearce and Ruyle (1938), Pearce (1940), and Williams (1940) suggested that the prevention of spoilage depended upon the control of contamination and rigid application of principles of sanitation in the preparation of the product.

As an added precaution for the 1940 season, it was suggested that the filling temperature be maintained at around 190° F. and that the process for the No. 2 can be 45 minutes at 212° F. This process was considered by many as the maximum process that could be used and still retain good quality in the finished product.

In tests employing conventional and "flash" processes on inoculated raw tomato juice, using 20,000 spores per milliliter of *B. thermoacidurans* (laboratory strain No. 94S), destruction was nearly complete in "flash" processed juice having a calculated sterilizing value equivalent to 0.73 minute at 250° F. and was definitely completed at $F_o = 1.1$. The results of these tests are given by Wessel and Benjamin (1941).

From many unpublished results on thermal death time tests employing the multiple tube technique, practically all strains were destroyed at a sterilizing value corresponding to 0.7 minute at 250° F. The choice of a sterilizing value equivalent to $F_o = 0.7$ seemed to be a reasonable one for the commercial application of the method since the maximum resistance seemed to be around this value. An equivalent boiling water process for a No. 2 can of juice with an initial juice temperature of 170° F. would be about 140 minutes at 212° F. Such a long cook would, of course, cause much quality deterioration, but it clearly indicates the exceptionally high heat resistance of this spoilage organism.

Since no loss in quality was found in the juice packed by the "flash" sterilization procedure, which later was termed the pre-sterilization method, commercial installations employing this method were placed in use during the 1941 canning season.

A commercial comparison of the sterilizing efficiencies of the conventional and pre-sterilization methods on identical juice from the same raw juice tank was conducted by this laboratory in 1942. Cans from the two parallel packing lines were obtained after water cooling. Bacteriological tests showed the "flash" processed juice to be completely sterile, whereas at least one flat sour microorganism per milliliter of can content survived the conventional cooks. Some spoilage was encountered by the packer in the conventionally packed juice, but none in the "flash" processed juice.

As a result of these early successes, many additional canning lines have been converted to the pre-sterilization method. Approximately 50 pre-sterilization units of various types were in operation during the 1945 canning season and many more are projected for the coming season. Canners have found that in addition to guarding against flat sour, off-flavor spoilage, the pre-sterilization method provides a continuous flow system which results in saving of labor.

Recent data indicate that the ascorbic acid content for pre-sterilized juice does not differ from that obtained for identical juices processed by conventional methods. As for conventionally processed juices, it is essential to guard against the exposure of the juices to oxygen in order to retain a high level of ascorbic acid.

BRIEF DESCRIPTION OF CANNING PROCEDURE

The commercial application of the pre-sterilization method consists of heating the prepared juice rapidly and continuously to a temperature of 250° F. to 280° F.,

depending somewhat upon the type of heat exchanger employed, and rapidly cooling to a temperature below the boiling point before filling. The juice is filled at a minimum temperature of 190° F. and held for 3 minutes before water cooling. The "high-short" process is designed to destroy spores of heat-resistant, soil-borne microorganisms and the "high" filling temperature and the short hold before water cooling serves to kill bacteria of low resistance that re-enter the product during filling.

During the summer of 1945 representatives of laboratories connected with the canning industry agreed that from a theoretical point of view the following closing temperatures with a subsequent holding time in air after closing have approximately equivalent sterilizing values [Cameron (1946)]:

Closing temperature	190° F.	200° F.
Holding time before water cooling	3 min.	1 min.

Since there may be practical difficulties in consistently maintaining the higher closing temperature, use of the lower closing temperature with longer holding time provides an operating safety factor. In addition, more difficulties will be experienced with slack filled cans, and paneling of the larger size cans, when using the higher closing temperature.

Care is exercised in sterilizing the entire equipment contacting the juice with water at around 240° F. for 10 minutes before admitting the juice.

EQUIPMENT

Usually the expressed juice is collected in a corrosion resistant metal or glass lined tank which supplies the pre-sterilizing units. This tank, having a capacity of 600 to 1,000 gallons, should be furnished with a stirrer to maintain uniform distribution of insoluble solids in the juice. The stirrer should cause gentle rolling of the juice rather than a violent mixing which may cause the occlusion of air.

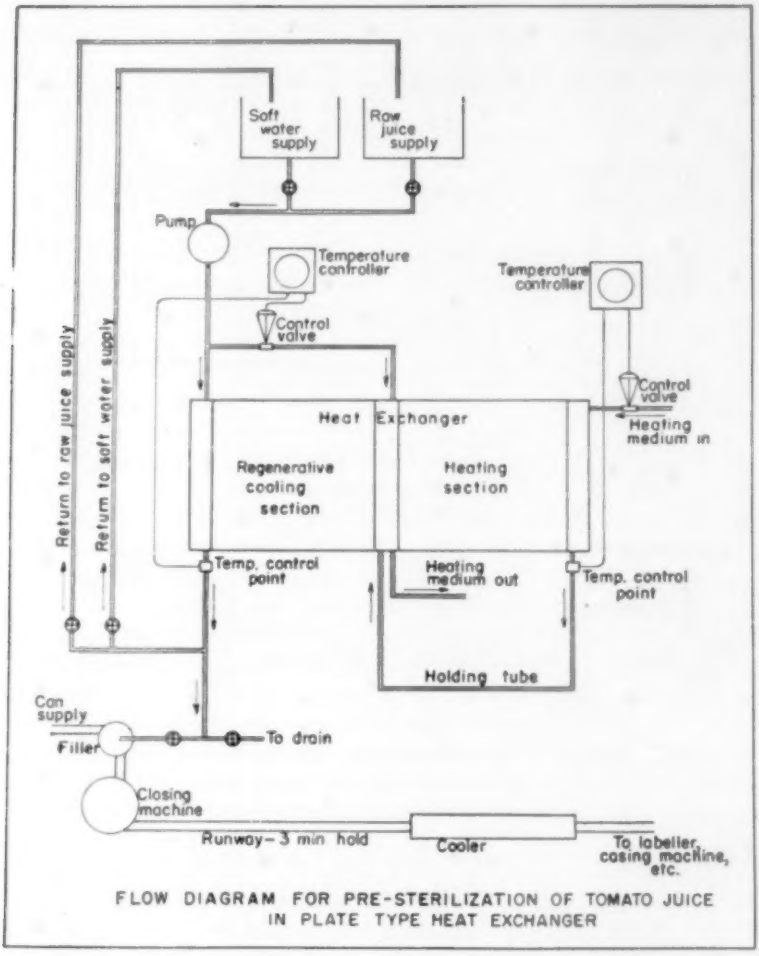
Coil heat exchangers, plate heaters and tubular heat exchangers (see flow diagrams) have all been employed in the pre-sterilization of tomato juice. Certain conditions should be considered in judging the merits of a particular type of equipment, such as the thermal efficiency, the ease of cleaning the heat exchanger surfaces, and the available means of automatic control of pre-sterilizing and filling temperatures. In estimating operating costs, the heat requirements for a non-regenerative system should be weighed against those for a regenerative system; also cooling water is required for the non-regenerative system and this should be considered in cost estimation.

The heat exchanger must be designed to withstand the pressures necessary to pump the required amount of juice (30 to 60 gallons per minute) through the equipment, as well as being capable of heating the juice to the sterilizing temperature. The cooler should be capable of cooling the sterilized juice to the proper filling temperature. The gaskets used should withstand temperatures of 250° to 300° F. over reasonable periods of time, and if they contact the juice, must be made of some innocuous material. The pressure drop through the cooler should exceed the pressure of saturated steam at the maximum temperature in the heater, otherwise, boiling within the heat exchanger is apt to occur which reduces heat transfer efficiency.

If a 250° F. process is used, a holding time of 0.7 minute at 250° F. has been suggested for sterilization with respect to *B. thermacidurans*. This holding time is effected by connecting a pipe of sufficient capacity in the juice line between the heater and cooler. At 265° to 280° F. the entire process may be accomplished by bringing the temperature of the juice up to these temperatures. The temperature

needed depends largely upon the particular rate at which the juice is heated and the particular type of equipment used.

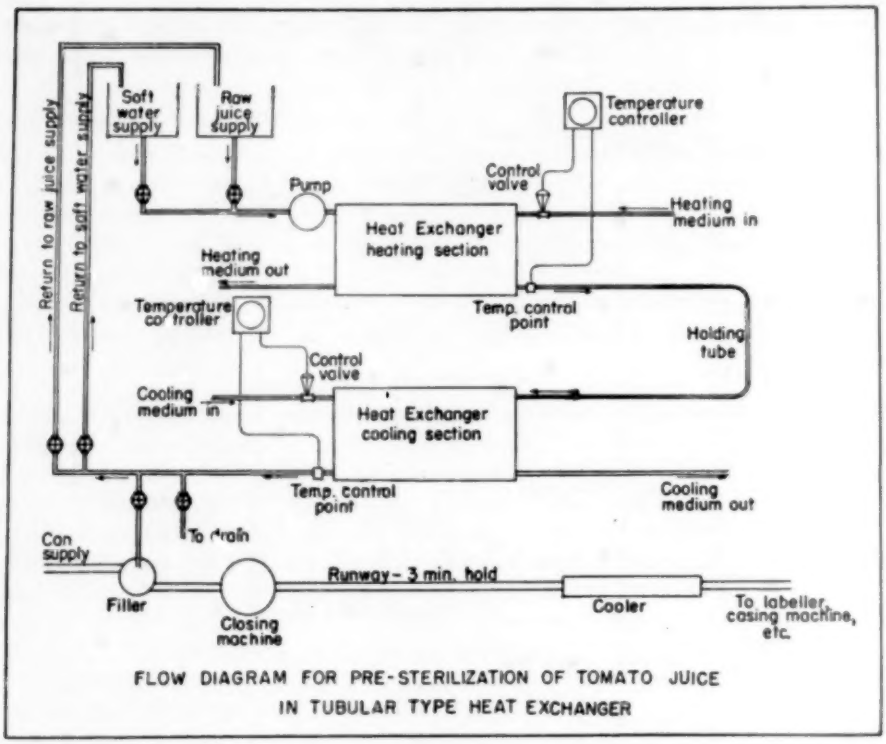
The pump used must maintain a positive and constant rate of flow against the pressures necessary for forcing the juice through the equipment. Maintenance of volumetric efficiency over the full season's operation is important.



FLOW DIAGRAM FOR PRE-STERILIZATION OF TOMATO JUICE IN PLATE TYPE HEAT EXCHANGER

Control instruments capable of automatically maintaining the desired sterilizing and filling temperatures are invaluable in the operation of equipment of this type. Recording type control instruments are desirable to maintain a continuous record of each day's run. They not only aid in keeping the operator alert, but furnish means of checking the heat treatment of any given lot if any question arises after the packing season. In order to check the automatic temperature recorders, the sterilizer should be equipped with mercury-in-glass thermometers (approximate range 70° to 300° F.), installed at identical points in the heat exchanger. If there is a discrepancy between the automatic record and the mercury thermometer, the correction should be made in the recording instrument by adjusting the pen to record the exact temperature of the mercury thermometer. The mercury thermometers should be checked each year against a standard thermometer.

After the juice has been pre-sterilized and cooled to the proper filling temperature, cans are filled and closed on standard equipment. The closed cans are elevated to cable runways which carry them in an inverted position for the required holding time to a spray spinner type cooler or any other type cooler which can be used in a continuous flow system. In a spinner cooler the cans are rotated on the long axis as they are conveyed under a series of water sprays. Another overhead cable runway conveys the cooled cans to the labeler and the casing machine.



FLOW DIAGRAM FOR PRE-STERILIZATION OF TOMATO JUICE IN TUBULAR TYPE HEAT EXCHANGER

PRECAUTIONS WHEN EMPLOYING THE PRE-STERILIZATION METHOD

During the past few years this laboratory has had opportunity to observe many installations of pre-sterilization equipment varying quite widely in detail. This experience has brought to light a number of points to which canners should give attention when changing from conventional processing methods. It was discovered, for instance, that it is difficult to impress on many operators the importance and purpose of a uniformly high closing temperature in each and every can. Without this realization, operators will tend to leave filled and unclosed cans in the line when the closing machine is stopped for any reason. If the shut-down lasts from 10 to 20 minutes, the average temperature of the juice in the open cans between the filler and the closing machine may drop below temperatures which are lethal for organisms which contaminate the juice during filling. This may explain occasional spotty spoilage when, for instance, 15 to 30 swelled cans are obtained in adjacent cases. The best way to avoid this kind of spoilage is to stop the flow of empty cans to the filler and close all the filled cans before stopping the filler and closing machine.

For some installations a flow diversion valve is used in the juice line between the sterilizer and the filler in order to prevent juice at lower temperatures than intended

from reaching the filler bowl. This is a valuable adjunct to sterilization after filling as juice is automatically returned to the raw juice supply tank until the proper filling temperature is reached.

In many installations a record is also made of the temperature of the juice in the filler bowl since this temperature is the only real check on the filling temperature. In this case it should be remembered that during filling and closing, the juice cools from 3 to 5° F. If the juice enters the filler bowl at 198° F., the temperature of juice in the can after closing may be 193° F. However, in the case of a shut-down, the temperature of the juice in the filler bowl may drop to 194° F. and lower, and the minimum closing temperature of 190° F. cannot be maintained. Where the delay does not involve the filler or closing machine, it is good practice to pack all the juice in the filler bowl before stopping these units in order to prevent the temperature from dropping below the lethal range for destruction of organisms of ordinary spoilage types.

In case the closing machine should be jammed by a bent can and delay canning operations, it may be necessary to empty the filler and carry the juice back to the supply tank, or if this is quite inconvenient, the canner may prefer to pack this juice at a lower closing temperature and give the cans a short still process followed by water cooling. Cans packed just after a shut-down may also be set aside for air cooling and stacked separately for storage observation before admitting these cans to the regular warehouse stock.

In several instances, it was found necessary because of the space required, to install the holding runways and the coolers outdoors, above or alongside the factory buildings. In some instances no provision was made to cover these runways. During rainy weather, the purpose of these holding runways would be defeated in that a high rate of spoilage could develop in cans which were immediately cooled to sub-lethal temperatures by falling rain. A covering of some sort should be provided for the holding runways when outside installation cannot be avoided.

The cable runways should be furnished with automatic devices for stopping them whenever a jam occurs anywhere along the line. Such devices will prevent cable burns and cuts which often result in appreciable spoilage.

Rough handling of cans and excessive denting of the seams in automatic, high speed conveying of filled cans may also result in spoilage. Bumps, especially on the seam before the compound has a chance to "set," may frequently be a major factor contributing to a persistent abnormal spoilage rate. Filled cans suffer considerable damage rolling down unbraked runways, either colliding with adjacent cans, with bars on elevators, or in the casing machine. Gravity drops instead of lowerators for filled cans have also been responsible for considerable can damage.

Positive progression, bar type spinner coolers eliminate many of the difficulties experienced with coolers which depend upon entering cans to discharge the cooled cans. If the flow of cans to the non-positive type of cooler is interrupted, the cans in the cooler will remain there until the obstruction is cleared away and the flow of cans again enters the cooler. The cans are then overcooled, the labeler may not label wet cans, and rusting troubles are also invited since there is not sufficient residual heat to dry the cans before casing.

When juice is being pre-sterilized, there is some tendency for a thin film of solids to bake onto the heat exchange surfaces during long continuous runs. The rate at which this coating forms is related to the linear velocity of the juice past the heat exchange surfaces. The heating efficiency decreases in proportion to the thickness of the burnt-on film. Whenever the heating efficiency decreases to a point where it is necessary to stop for cleaning, appreciable time is needed if the equipment must

be dismantled and manually scrubbed. The problem at the peak of the canning season is to keep the equipment running for 10 to 12 or more hours per day without having to dismantle and clean. For certain juices this can easily be done. For other juices it will be necessary to clean after an 8 to 10 hours' run. Suppliers of detergents have worked on this problem and cleaning solutions have been found, which when circulated through the equipment between shifts, remove the insulating film and restore the heating efficiency of equipment without having to dismantle and clean. However, at the end of each day's run it is good housekeeping to dismantle and inspect all equipment in order to insure complete cleaning.

As for conventional canning of tomato juice and blended juices, sanitary clean-up procedures also involve thorough washing of tanks, conveyor belts and juice machines during night or meal time shut-down periods. Further, the pumps and fillers should be dismantled daily to insure adequate cleaning. Wooden equipment should be eliminated and "dead ends" in the pipe system should be avoided since these are sources of bacterial growth and infection. Rigid inspection should also be provided to see that the clean-up precautions are efficiently carried out.

SUMMARY

Commercial experiences over the last five years indicate that the pre-sterilizing method, as applied to the canning of tomato juice and tomato juice cocktail, has offered more positive control with respect to flat sour spoilage than could be possible in a still processed juice. This has been accomplished, without causing any deleterious effect on the quality of the product, by taking advantage of greater bactericidal effects accompanying an increase in the rate of heat penetration into the product when heated at elevated processing temperatures in heat exchangers.

The success of the pre-sterilization method depends largely upon accurate control of pre-sterilizing and filling temperatures.

Although flat sour spoilage has not been reported in pre-sterilized juice, this does not mean that there should be any slackening in sanitary precautions. In fact, certain precautions not inherently required for the conventional method must be exercised for the successful packing of tomato juice by the pre-sterilization method.

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A METHOD FOR THE PRODUCTION OF DRY POWDERED ORANGE JUICE[1,2,3]

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The Food Technology Laboratories, M.I.T., were assigned the problem of developing a method for the production of dry powdered orange juice by the Office of the Quartermaster General United States Army. This work was requested, since it was impossible to ship fresh oranges to most of the overseas areas or to use them in combat rations. Several types of synthetic fruit juice powders were in use at that time, but they had the serious drawback of lacking the flavor, and natural vitamin and mineral content of fresh orange juice. It was believed that powder made from fresh orange juice could obviate these deficiencies.

Since normal orange juice consists of from approximately 80 to 86 percent water, the saving in shipping space and weight by a process which would remove most of the water was obvious. A further consideration was the fact that the keeping qualities of such powder, over fresh orange juice, were much greater.

Orange juice solids consist chiefly of invert sugar, sucrose, and citric acid in sufficient quantities to make the drying of orange juice a particularly difficult problem. The vapor pressure of orange juice solids of 1 percent moisture content is approximately 1 mm. of mercury at room temperature. This not only makes the dried material very hygroscopic, but makes it difficult to reduce the powder to a low moisture content in the first place.

For these reasons the original approach to the problem followed the technique and experience of those working in the field of blood plasma drying, and the initial work was directed toward utilization of dehydration from the frozen state.

After considerable work had been carried out, it became evident that this method would be quite expensive and, as will be shown later, was not necessary to produce a satisfactory powder.

The fundamental approach to drying from the frozen state, however, produced data which subsequently proved most useful. These data have been published by the Office of the Quartermaster General in a series of three reports covering the activities of the Food Technology Laboratories at M.I.T. for the years 1942-1945 inclusive.

This present paper is limited to the description of the process, and pilot plant equipment which resulted from this work.

In essence the process which has been developed consists of exposing a thin film of concentrated orange juice to vacuum, and employing heat input by radiation. The concentrate is fed into the equipment and removed as a powder on a continuous basis.

The advantage of using a previously concentrated juice can readily be seen when it is pointed out that vacuum equipment is relatively expensive in commercial

[1] We should like to acknowledge the excellent work of the members of the Food Technology Laboratory Staff at M. I. T. in connection with this project as well as to express our appreciation to Artisan Metal Products Inc., Boston, for their aid and cooperation in the design and construction of the pilot plant drier.

[2] The work covered in this paper was undertaken in cooperation with the Office of the Quartermaster General, Washington, D. C.

[3] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 16, 1946.

practice. Any method of pre-concentration may be used provided that the juice is not seriously injured in flavor, color or vitamin content by the process. The standard type vacuum pan is one of the obvious methods, provided there is sufficient vacuum. Using this procedure, a large proportion of the water in the juice is removed by a simple and relatively inexpensive method.

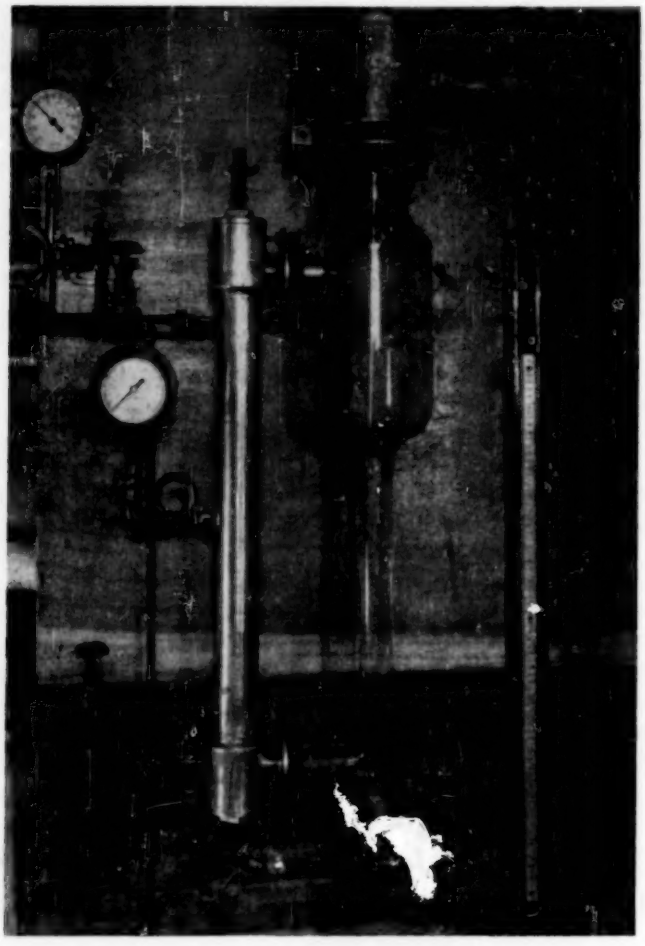

FIG. 1. Laboratory vacuum evaporation.

In the laboratory and pilot plant work a small vacuum evaporator of the batch type as shown in Fig. 1 is used. The entire system is held at a low pressure, approximately 5 to 10 mm. of mercury, so that the boiling of the orange juice takes place at low temperatures. This enables the concentration of the product without heat damage. Fig. 2 shows a schematic diagram of the evaporator. The material to be concentrated is drawn into chamber A by atmospheric pressure, and steam at approximately 5 pounds pressure is directed through the steam jacket. The boiling of the liquid takes place almost immediately when the heat is applied. The water vapor resulting from the evaporation is pumped away and condensed. The boiling of the liquid and the escape of the water vapor in the stainless steel column causes a circulation of the juice in a clockwise direction as shown by the arrows in Fig. 2.

Evaporation occurs at a rate of approximately 2.5 gallons of water per hour, and additional juice can be drawn into the system without disturbing the operation.

Early experience with the drying of concentrated orange juice under vacuum showed that thin films of the product did not remain in flat layers during the drying but, rather, "puffed up" or inflated on the drying surface. This behavior seriously interfered with heat input to the product by means of conduction and for this reason radiant energy was chosen as the main source of heat input. The inflation of the concentrated orange juice film, however, proved to be of considerable advantage, since it served to increase greatly the surface area of the product, which resulted in a drying cycle of approximately 9 minutes as compared with several hours when drying from the frozen state was employed.

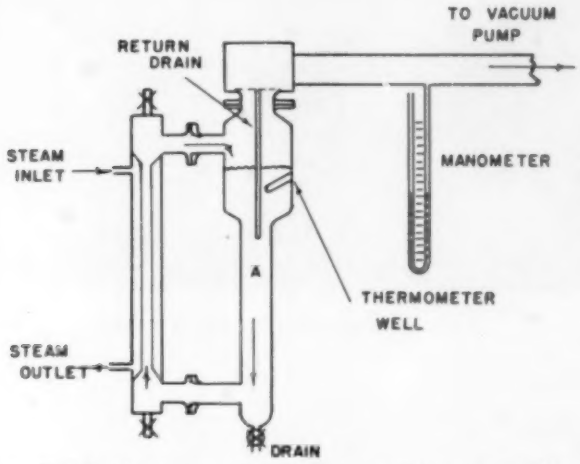

FIG. 2. Sketch of vacuum evaporation in vertical cross section.

The pilot plant machine consists of a large cylindrical tank connected by means of large diameter piping to a steam jet evacuator system that maintains a low pressure in the tank. An external view of the drier is shown in Fig. 3. Within the tank is an endless stainless steel belt which is rotated in a clockwise direction by a motor outside the tank. The concentrated juice is introduced into the tank at one end and is distributed by a feed box mechanism in a uniform, thin layer on the moving belt. The belt carries the orange juice under a series of infra-red lamps; the heat from these lamps produces a dry powder from the juice. A platen supplied with cold water over which the belt passes is available to cool the product at the end of the drying cycle. By the time the product has reached the far end of the tank, it has been dried to a brittle sheet. This is removed from the belt and broken up by a doctor blade. The resulting powder is collected in a hopper, and is then packed and sealed in sanitary cans under the original vacuum of the system.

Fig. 4 shows a line drawing of the external construction of the pilot plant machine. The external steel shell is cylindrical in shape and has a total length of approximately 15 feet and an internal diameter of approximately 3½ feet. Vacuum tight sight glasses have been provided along the length of the shell to permit observation of the product during the drying cycle. At the left hand end of the drier as shown in Fig. 4 is a feed input tube through which the product is introduced into the tank. At the right end is a motor equipped with a variable speed Reeves drive which rotates the stainless steel belt within the tank. Internal lighting fixtures of

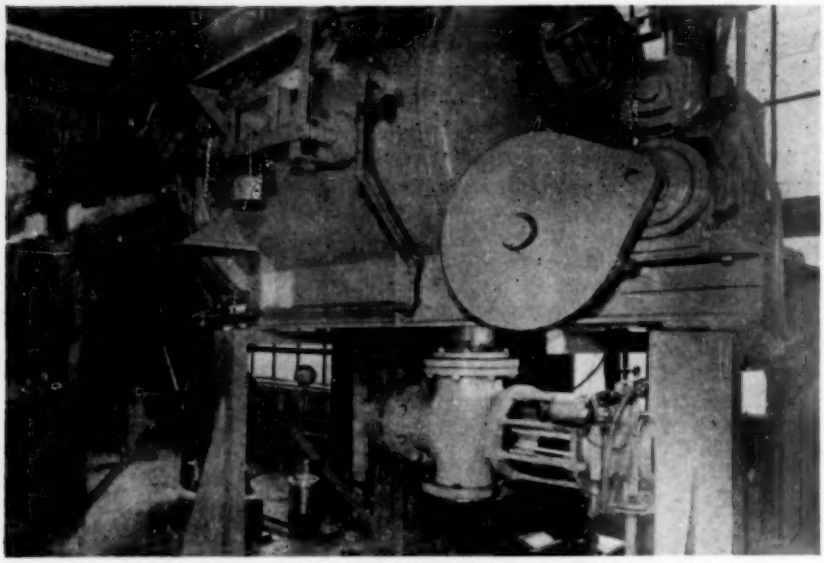

FIG. 3. Pilot plant vacuum belt drier.

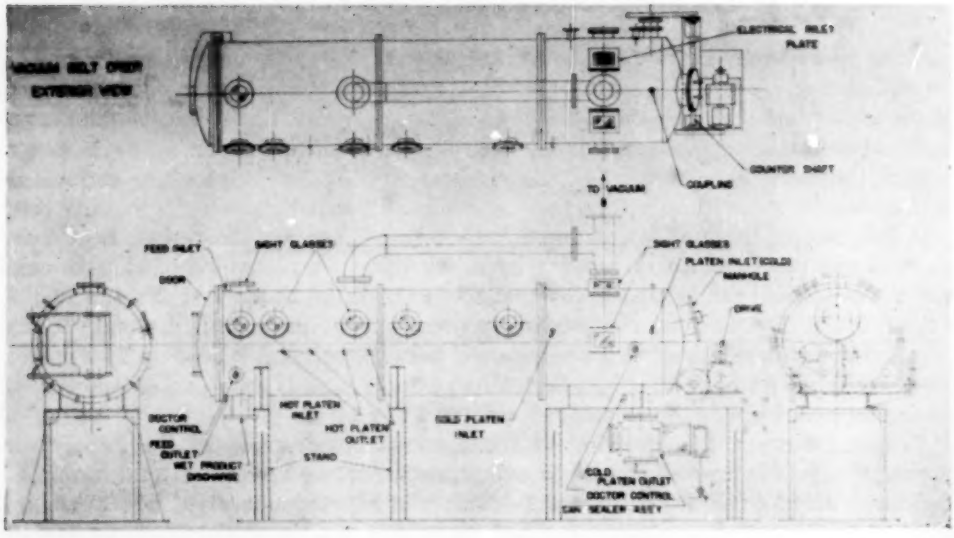

FIG. 4. Line drawing of pilot plant vacuum belt drier showing external construction.

the fluorescent variety are provided to render the interior of the tank visible. A brass plate in which porcelain insulated conductors have been soldered serves as an entry for all of the internal wiring of the drier. Various types of vacuum gauges have been used to measure the pressure within the tank during the experimental and development work. Tilting MacLeod gauges are used at both ends of the drier tank.

In order to produce a vacuum within the drier, a three stage steam jet evacuator system is used. The arrangement of this system is shown in Fig. 5, one ejector

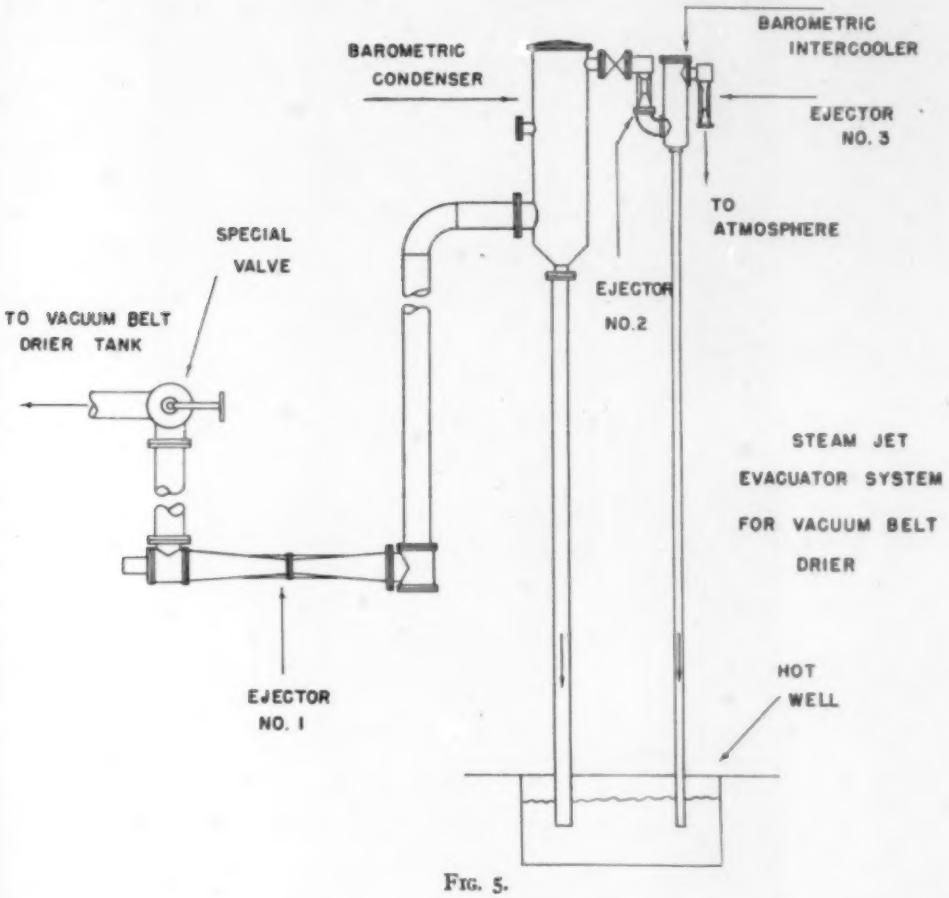

FIG. 5.

connecting directly to the drying tank through a large diameter hand operated valve of special design. This ejector discharges into a barometric condenser in which the condensible water vapor entrained by the ejector is removed and leaves the system through a 34 foot tail pipe and a hot well as shown. The barometric condenser is of the counter flow type. A second smaller ejector connects with the top of the barometric condenser, removes the non-condensible gases and raises their pressure considerably. These gases pass with the steam from the jet into a barometric intercooler in order to condense the steam which is removed with the condensing water through a second tail pipe which extends into the hot well as shown. A third ejector entrains the non-condensible gases, increases their pressure, and discharges

them to the atmosphere. The system includes steam lines with the necessary controlling valves, strainers, and traps in order to supply dry steam to the ejectors in the required amounts. The main steam line pressure is approximately 130 pounds.

Experience with this equipment has shown that satisfactory results can be obtained with orange juice when the operating vacuum is in the neighborhood of 1.2 mm. of mercury. This is fortunate, since the expense of pressures lower than this is much greater. This relatively high pressure is of considerable practical importance since it decreases the construction and operating costs of the equipment.

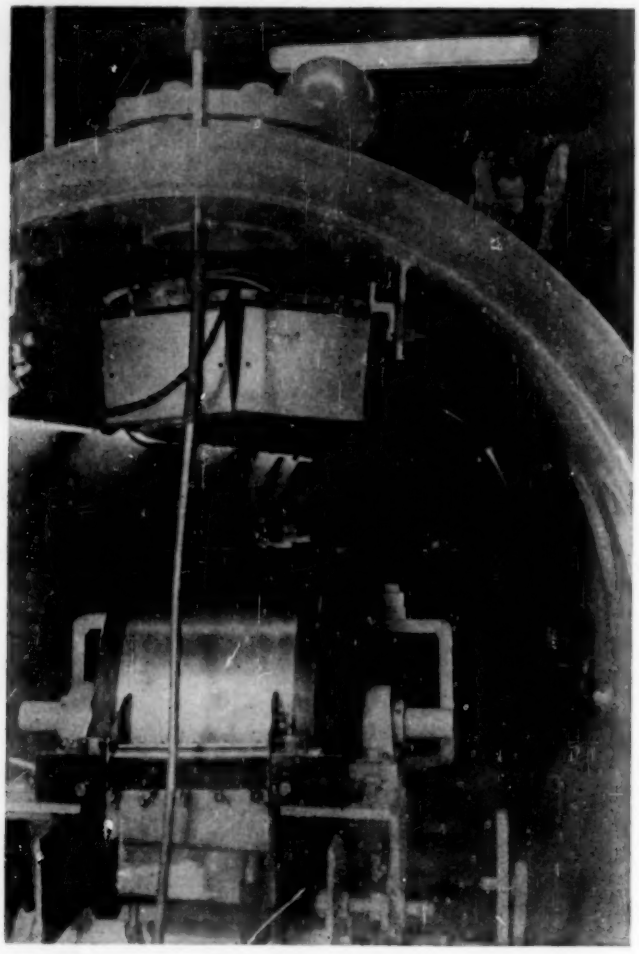

FIG. 6. Interior of pilot plant vacuum belt drier, feed end.

As previously mentioned, heat is supplied to the product by means of radiant energy from a series of infra-red lamps. This type of radiant source was chosen for convenience, but other types of radiant heat sources such as open nichrome wire or steam coils may prove to be adaptable in commercial practice. Fig. 6 shows a photograph of the interior of the drier from the feed end, and Fig. 7 shows a line drawing of the internal mechanism. As can be seen from these figures, the infra-red lamps are arranged in a series of five banks, each bank being two rows wide. Each

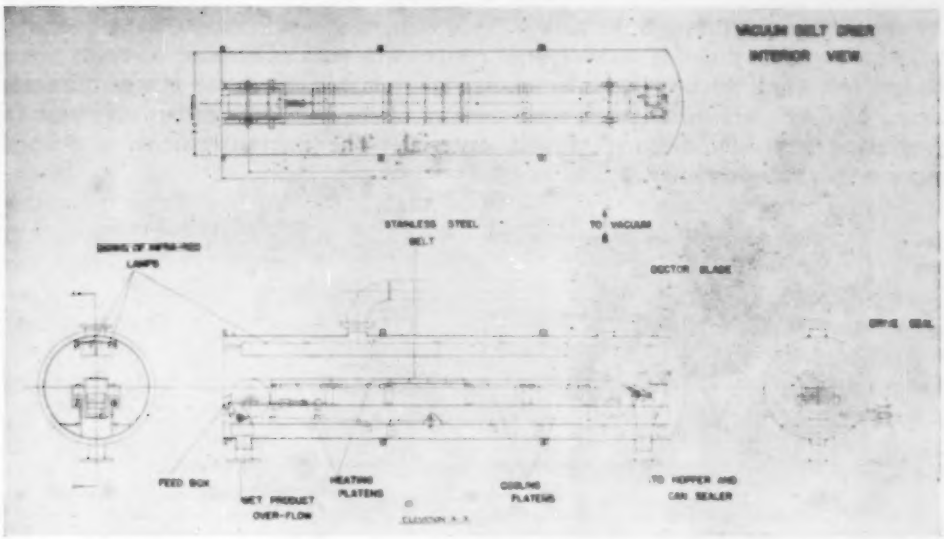

FIG. 7. Line drawing of pilot plant vacuum belt drier, showing internal construction.

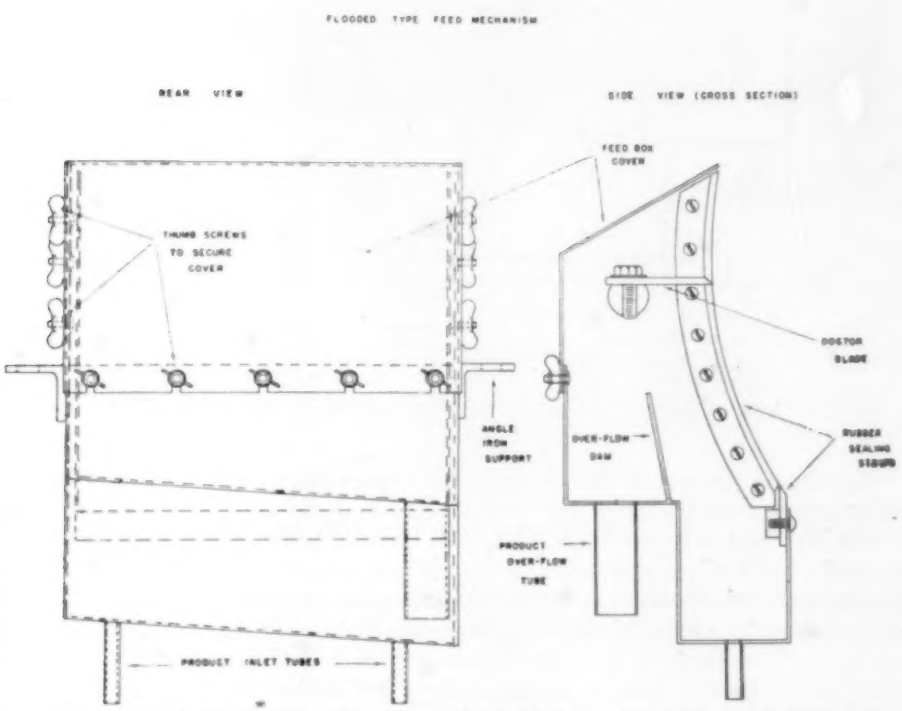

FIG. 8. Flooded type feed mechanism, which deposits a uniform film of material.

bank of lamps is wired separately, and control is obtained by having a separate switch fuse box, Variac, and meter for each bank. The heat produced is controlled by the voltage put through the lamps. This voltage, which is regulated by Variacs, offers a complete range of control from zero to 110 volts. Consideration was given to supplementing the heat input by conduction, but this has so far proved unnecessary. Cooling platens, however, near the end of the belt have proved of value in producing an easily doctored, brittle material. The thermoplasticity of orange juice makes this necessary.

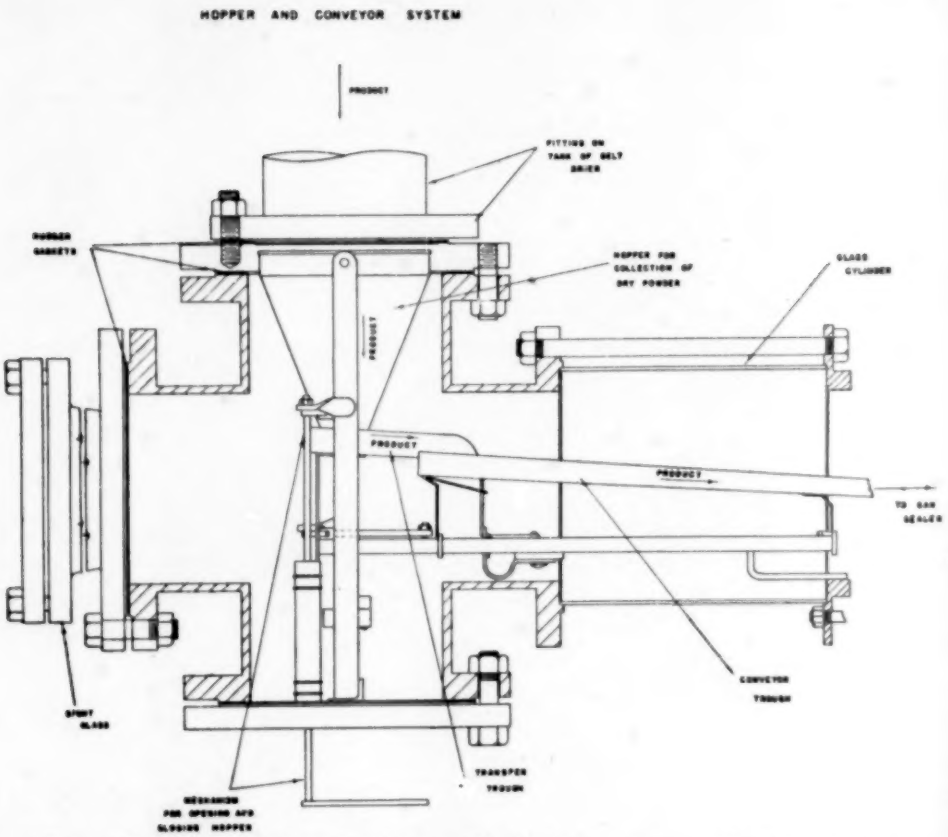

FIG. 9. Sketch of finished product hopper with discharge conveyor and adjacent parts.

The drying surface for the concentrated orange juice is constructed of stainless steel 0.020 inch in thickness and is welded to form an endless belt approximately 28 feet long and 8 inches wide. This belt passes over two flat-ground steel rolls mounted on self aligning ball races. The belt is under spring tension and the roll diameter selected, 1000 times the belt thickness, has proven quite satisfactory. The belt is driven by means of an external motor, previously described, which rotates the steel roll on the take off end of the belt by means of a chain drive. The drive connects with the roll shaft by a vacuum tight seal in the tank. V-type idler pulleys on the underside of the belt aid in the alignment. The effective area for drying, that is, the amount of area under the effective range of the infra-red lamps at any one time, is 5.2 sq. ft. By means of a Reeves drive on the drive motor the belt speed can

be varied from 0.5 to 3.3 feet per minute. It has been found helpful in the case of orange juice to roughen slightly the surface of the belt with emery cloth to increase the wetting ability of the surface.

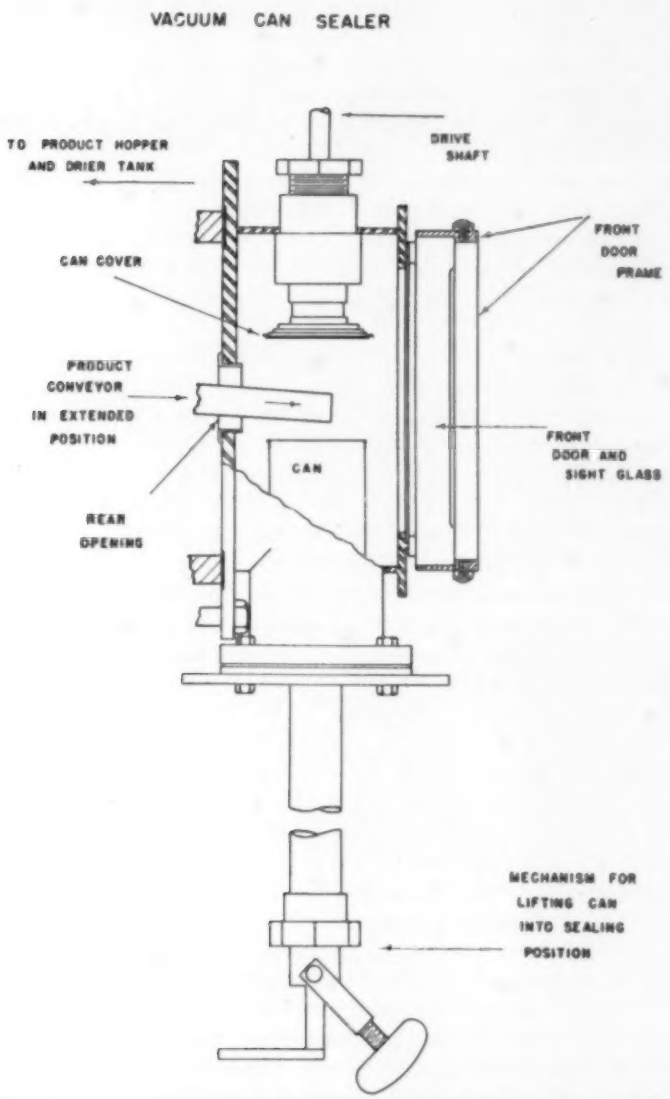

FIG. 10. Sketch of vacuum can sealer, with movable product feed conveyor and adjacent parts.

One of the most important problems in the entire process has been the development of a feed mechanism which would deposit a continuous and uniform film of material on the surface of the belt. A further requirement was that this film be of known thickness and that this thickness be capable of adjustment. One possible solution to this problem was achieved by the mechanism shown in Fig. 8. In operation this chamber is placed against the feed end of the belt as indicated in Fig. 8 and orange juice concentrate is pumped into the box until the concentrate

just begins to flow over the dam into the overflow box and out through the overflow tube. The concentrate is contained within the feed chamber by the closeness of the fit between the feed box and the rotating belt. As the belt moves forward it picks up a layer of concentrate. An adjustable doctor blade is available by means of which the thickness of the layer can be regulated. This type of flooded feed has proved successful in preliminary runs.

The doctor blade, located at the take-off end of the belt when in the operating position, rests against the belt and the ground surface of the roll beneath it. The blade is so pivoted that it may be rotated away from the belt to permit the by-passing of the product if desired.

It has not been found necessary to employ some type of grinding procedure within the machine to reduce the dry concentrate to a powder since sufficient breaking up of the material for development work occurs during the doctoring process. In a commercial operation, however, it would probably be desirable to reduce the dry materials to as fine a powder as possible in order to increase the packing density.

The powdered orange juice, after being removed from the belt by the doctor blade, drops into a hopper as shown in Fig. 9. This hopper is equipped with a slide, which can be opened to allow the material to fall onto a vibrating conveyor below, and an electromagnetic vibrator which serves to vibrate the hopper thus aiding in emptying it and preventing the bridging of material within. The vibrating conveyor, which lies directly below the hopper, is a metal trough which extends forward through a section of glass cylinder toward the can sealer. The glass cylinder permits observation of the product. This trough can be extended forward into the sealing chamber by means of a lever during the filling operations.

The can sealer is shown in Fig. 10 and consists of a chamber within which is a sealing head, a holder for the can top and a movable base for the can itself. In the rear wall of the chamber is an opening or port which connects with the drier system and is in line with the trough conveyor. This port can be closed by a valve mechanism. The front of the chamber consists of a large sight glass which can be swung in position and seats against the chamber on a rubber gasket forming an air tight seal. In operation an empty can is placed in the chamber, the front door is closed, and the chamber is evacuated with a mechanical pump. When the pressure is equal to that in the tank, the rear port is opened and the conveyor is extended so that it discharges into the can. When the can is full, the conveyor is retracted, the rear orifice is closed and the can is raised to its cover and sealed. The vacuum on the chamber is then released and the can removed. In this way the product is canned under the original vacuum of the system and does not come in contact with the atmosphere, so that moisture and oxygen from the air are excluded from the product.

Exact engineering data on the process are not available at this time, but preliminary runs indicate a satisfactory result. The production of a dry powder having a moisture content of below 1.5 percent has been accomplished. The color and taste of the powder as well as the vitamin C content appear to be unimpaired by the process. Rapid reconstitution of the powder indicates excellent solubility.

Although the work is still in a preliminary stage and any estimations of commercial use would be premature, the indications are that a method is now available by which a dry orange juice powder of high quality can be produced commercially on a continuous basis. Such material should find use in Army and general civilian markets, and elsewhere when the procurement of fresh orange juice is difficult, or where the problems of shipping space and weight are important.

SOME ASPECTS OF FOOD PROCESSING EQUIPMENT DESIGN FROM THE STANDPOINT OF HEAT TRANSFER[1]

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The broad subject of heat transfer in the design of food processing equipment would require several books to cover and therefore in presenting this paper I wish to emphasize its survey character and that it is not conceived of as or presented as a fundamental contribution.

Heat is transferred by radiation, conduction, convection, each having obvious fields of application. I would like to emphasize that each is subject to rational analysis and that quite accurate calculations may be made using well developed engineering equations. However, probably of greater value to each of you would be a knowledge of the effect of the variables in the system—with this knowledge you could rationally appraise all heat transfer operations involved in your plants or in the problems you are working with and know how to obtain better heat transfer conditions which generally will yield a better product at lower cost. Everyone involved in food processing should have this type of knowledge as a minimum.

Since heat transfer by conduction and convection combined is perhaps of widest interest and since its presentation will show the variables involved and the method of tackling problems, the analytical part of this paper has been limited to presenting this phase of heat transfer. We will examine the theoretical basis and then consider some practical applications.

PICTURE OF HEAT TRANSFER MECHANISM

Fig. 1 shows a rational picture of how heat flows from one fluid to another through a wall. The concept of resistances to heat flow by films of, say, gas or liquid on either side of a separating material such as a tube wall is clearly shown. The fact that there is a temperature drop through each film and through the wall is graphically indicated. It is important to note that the films are generally controlling the heat transfer, and the heat transfer through the metallic wall itself (its thermal conductivity) is only one factor and frequently a minor one in the overall transfer of heat from one fluid to another.

OVERALL HEAT TRANSFER EQUATION

The conventional equation for heat transfer is:

$$\frac{Q}{\theta} = UA\Delta t \qquad (1)$$

This simply says that heat transfer is a function of an overall coefficient of heat transfer U (which is not constant and which varies throughout a batch operation, but which is constant in any point in a continuous process) to the area A and to the temperature difference Δt across the system involved. These factors are all quite obvious.

To use this basic equation, however, requires a knowledge of how to calculate the overall coefficient of heat transfer. Much work has been done on this and those who are interested should consult W. H. McAdam's "Heat Transmission" *(3)*. There you will find rational analyses of most types of heat transfer phenomena and you'll note that the variables are generally the same but they effect results in different

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 16, 1946.

degrees as physical conditions change—thus, transfer in vertical tubes is different than in horizontal tubes, etc.

Some forms of apparatus do not allow a rational basis for heat transfer analysis —thus curved pipes, jacketed kettles, etc., are certainly not completely understood in their heat transfer characteristics. Wherever you find some simple type of correlation you undoubtedly should use it but do so with your fingers crossed and with a realization that unless it is based upon fundamental physics it is definitely not very satisfactory and should not be used beyond the range of conditions under which it was developed.

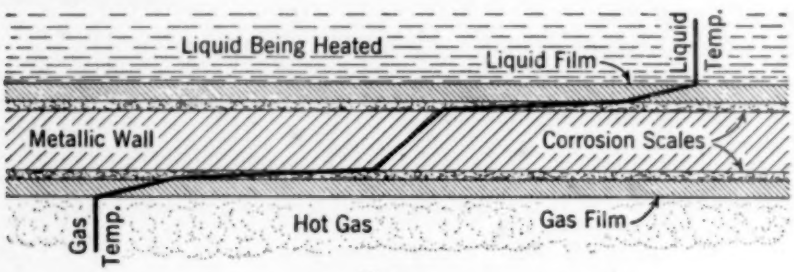

FIG. 1.

FIG. 1. A section through a metallic wall transferring heat from a hot gas to a cooler liquid, showing gas and liquid films, corrosion deposits, and the general effect of each upon the temperature gradient.

As an example of heat transfer calculations we may apply Equation I to heat transfer between fluids inside pipes, a process which is of considerable interest. Let us first consider it from the point of view of its mechanism and then of the variables affecting the heat transfer coefficient.

FILM COEFFICIENTS

We have already seen in Fig. 1 that the heat must flow through a film on either side of a wall and, thus, there are at least three different resistances to be considered besides the scale resistances which I am neglecting at this point since at least one side of food processing equipment should be free from scale. Each of these generally may be analyzed individually and in the case of fluids flowing through tubes, one analysis, limited to relatively non viscous materials such as water and to turbulent flow (Reynolds number over 2100) gives the Dittus & Boelter *(1)* equation:

$$\frac{hD}{k} = 0.0243 \left(\frac{DG}{\mu}\right)^{0.8} \left(\frac{C_p\mu}{k}\right)^{0.4}$$

This equation and others of a similar nature are generally presented in a graphical form because of the fact that conditions vary and that the equations are of use only over limited ranges. This equation for instance covers turbulent flow of liquids and is not satisfactory when the liquids are below the so called critical point (Reynolds number 2100) and are thus flowing in stream lined motion.

The variables in this equation are presented in what are known as dimensionless groups—that is

$$\frac{hD}{k} \qquad \frac{DG}{\mu} \qquad \frac{C_p\mu}{k}$$

are all groupings where the dimensions of the variables cancel out.

In passing I would like to mention that these should be in "consistent" units—that is, if the velocity is expressed in feet the diameter itself should be in feet, etc.

They are generally expressed in the English system, that is, pounds, hours, feet. One must be very careful to see that all dimensions which involve a length factor such as diameter D, lbs. of fluid flowing per square foot/hr., G, etc., are all in feet. Thermal conductivities k for instance is frequently reported in inches—thus, if you are unwary, putting a little factor of 12 in your "answer."

The important thing to note in the equation is that the mass velocity, G affects the individual film heat transfer equation to the 0.8 power—thus, if one doubles the velocity the heat transfer in the film affected is increased approximately 2/3.

Each of the other variables also has an effect but generally of less importance. However, it is obvious that one obtains better heat transfer when the fluid flowing is hot as the viscosity is decreased.

Note also that k the thermal conductivity of the fluid material is a factor—but only one factor.

Incidentally, I have never seen a compilation of viscosities of food substances, or a curve showing how food viscosities vary with temperature, although I have been informed that work has been done on chocolate by Joseph Stanley. There remains a great deal of engineering and physical work to do on this subject. Of course, many food items may be considered as water and data for that substance used. Or, one may assume that the viscosity is, say, twice that of water and work out an engineering answer which is better than just doing nothing rational and blaming it on a lack of data.

HEAT TRANSFER THROUGH A WALL

Next one has to calculate the equivalent heat transfer through the wall of whatever materials are being used. Since, by definition, k, the thermal conductivity of a material is the amount of heat one can transfer through it per hour, per square foot, per ° F. foot of thickness, this is equivalent to the h we calculated for a film—and all we have to do is divide by X, the feet of thickness of the wall. Thus

$$\text{Heat transfer through wall} = \frac{k}{X} \qquad (3)$$

If one considers the following values of k in B.t.u./sq. ft./hr./° F./ft. (all taken at temperatures in the range of 100-200° F. and all subject to slight variation because of composition, etc.)

Copper	220
Aluminum	130
Steel	38
Nickel	35
Stainless steel (Type 304)	9
Glass	0.6

you will note a very wide variation in the values of k and you know that glass even though it has a k 1/400 of that of copper requires only two or three times as long to transmit heat under more or less average conditions.

CALCULATION OF OVERALL COEFFICIENT

Having calculated, determined or assumed the individual h's and k, one may apply them in the following equation:

$$\frac{1}{U} = \frac{1}{h_1} + \frac{1}{k/X} + \frac{1}{h_2} \qquad (4)$$

to calculate overall U. I have done this for 2 metals assuming a condensing steam film coefficient of 1000, calculating a cooling water coefficient for water flowing

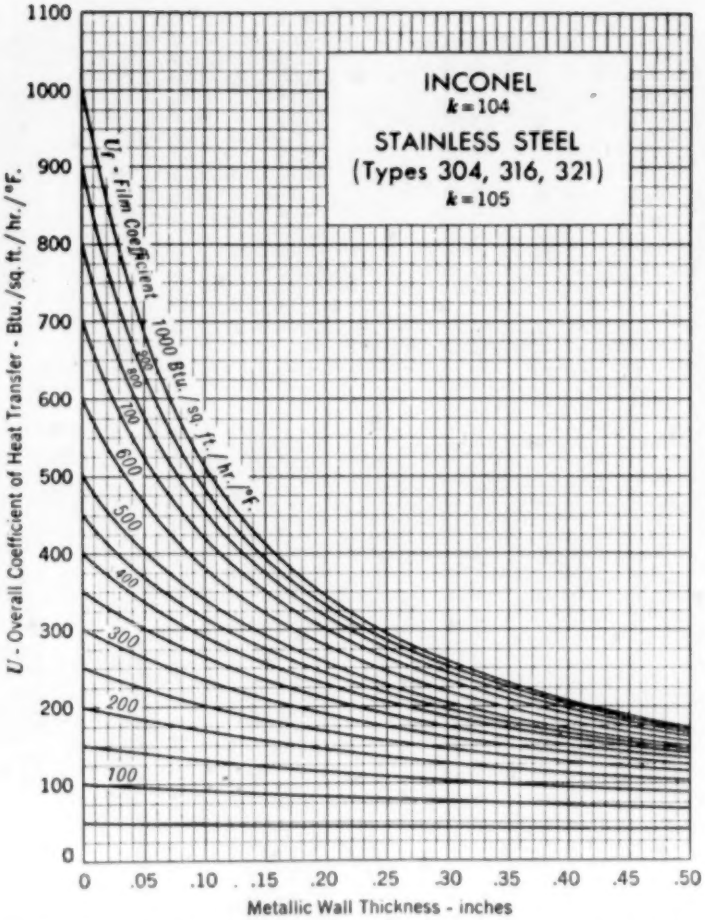

FIG. 2. Curves showing overall coefficient of heat transfer for stainless steel plate of any thickness up to ½".

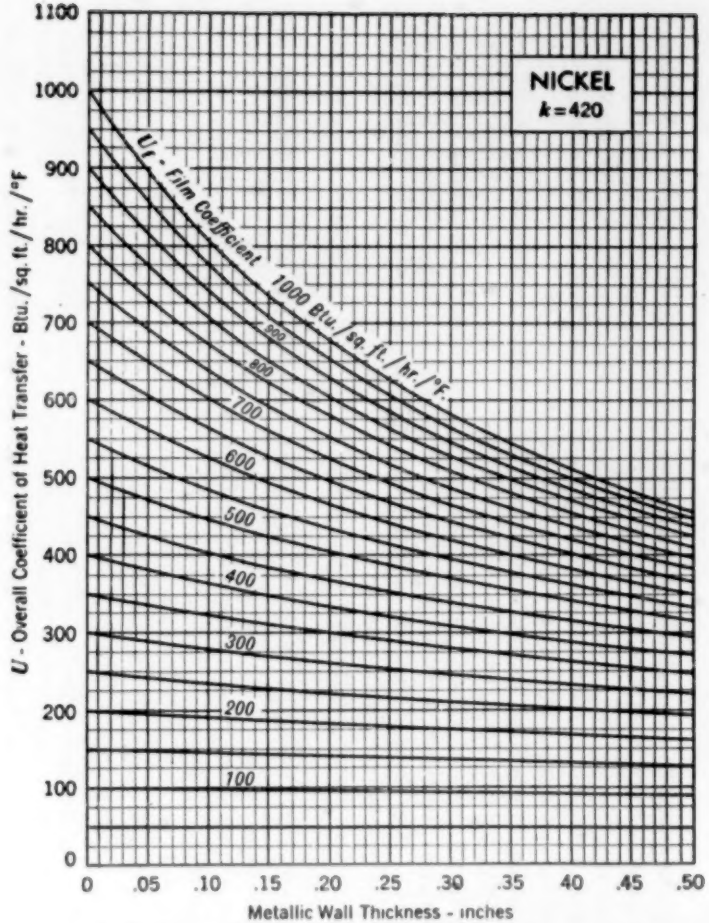

FIG. 3. Curves showing overall coefficient of heat transfer for nickel plate of any thickness up to ½".

through 1" pipe at 5 ft. per sec. as 700, and calculating X/k for ⅛" thick stainless steel, type 304, and for nickel.

For stainless,

$$\frac{1}{U} = \frac{1}{1000} + \frac{1}{9/181/2} + \frac{1}{700}$$

$$\frac{1}{U} = .001 + .0012 + .0014$$

$$U = 280$$

(Note near equality of each film or metal transfer coefficient or resistance)

For nickel,

$$\frac{1}{U} = \frac{1}{1000} + \frac{1}{35/1/1/8/12} + \frac{1}{700}$$

$$U = 370$$

Thus ⅓ more surface is necessary, all other conditions being identical, if one is to heat in stainless equipment, or expressed in time, for identical equipment size, under the conditions chosen, nickel equipment would heat up in ¼ less time. In designing equipment, you must consider the effect of each metal on product quality and the effect of heating time on quality. Also do not assume that all answers will be as in the problem presented.

The curves show that if you have very poor heat transfer coefficients the metal wall has practically no effect—but if you have good heat transfer, then, the metal wall has a very important effect.

EFFECT OF INCREASED SURFACE AREA

Besides the metal itself and the velocity of circulation there is an obvious quantity of ratio of volume to surface area of active heat transfer. Consider two conveyors jacketed to act as a heat exchange medium similar to that shown in Fig. 4.

The one on the right with heated drum instead of wide open spaces has approximately ¼ the holding capacity, and approximately two times the heating surface of the one on the left. Thus, it would be expected to require about ⅛ as long a time to bring the amount of product held by the one on the right up to any given temperature as would be required by the one on the left. Assuming that the next operation is to cool or do something else—then, this is a great gain. Of course, if the material is to be held for a long time at a high temperature the gain is of no value.

Plate type heaters have wide application, excellent heat transfer characteristics and are as nearly sanitary as any equipment so far designed. In one, the fluid flows through channel-like sections ⅓" x 1½", 20" long and reversing many times. This gives excellent agitation and along with small effective diameter and high velocity accounts for heat transfer coefficient on steam to water of 600 or better.

The widely accepted Votator has a method of minimizing films which is excellent and makes it very valuable in processing.

JACKETED KETTLES DATA

Plain jacket kettles are used throughout the food industry and the following data may be of interest.

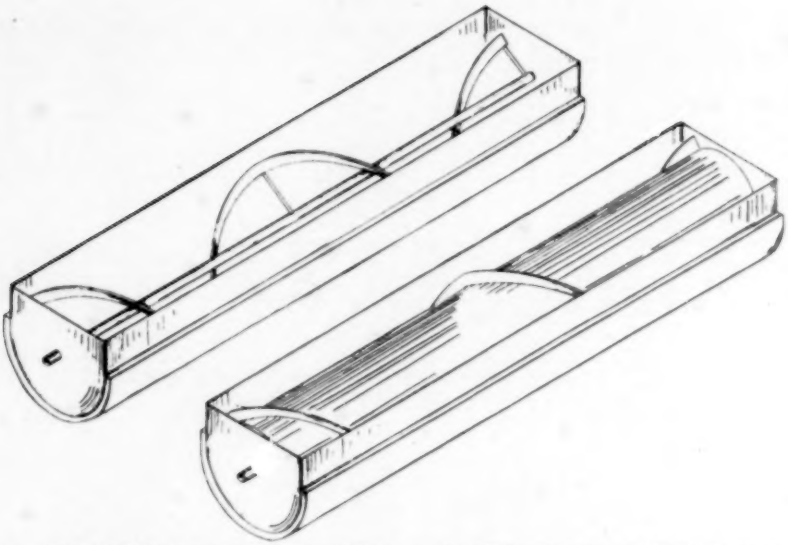

FIG. 4. Two jacketed conveyors, providing vastly different rates of heat transfer because one has a large volume steam chamber within the rotor, the other, no steam chamber within the rotor.

Using a 250-gallon kettle loaded with 840 lbs. of water, heated with 25 lbs. gauge steam and heating the water from 64° F. to 212° F.

Nickel kettle required 11 minutes.
Stainless kettle required 17 minutes.
Water then boiled off at the following rate:
Nickel—178 lbs. per 15 minutes.
Stainless—124 lbs. per 15 minutes.
Converting this to an overall heat transfer coefficient U (B.t.u./hr./sq. ft./°F) one has—

	Heating up	Boiling
Nickel	327	680
Stainless	200	475

In another test cooking down catsup at atmospheric pressure, conditions not otherwise recorded,

Copper kettles required 20 minutes.
Nickel kettles required 35 minutes.
Stainless kettles required 75 minutes.

For heating or cooling a batch one should consider scrapers or sometimes simply agitation. The well known Dopp kettles, now manufactured by Buffalo Foundry and Machine Company, capitalize on the value of close scraping of surfaces. Certainly, when handling thick materials there is a great advantage in scraping. Plain agitation, preferably with a turbin type agitator, increases heat transfer rates for fluids such as water and other low or medium viscosity fluids. In a paper entitled "Fundamental Principles of Heat Transfer," presented at the Food Technology Conference at M. I. T., June 3, 1939, Hottel and McAdams presented an interesting curve which showed the effects of cooling chocolate with and without scrapers. The Votator, as manufactured by the Girdler Corporation, capitalizes on this principle also, and, further, lends itself to continuous processing operations.

CHECK LIST OF DESIGN FACTORS

Partly in summary and partly trying to cover the whole field of equipment design from the standpoint of heat transfer, I suggest:

1. A rational analysis of all operations involving heat transfer.
2. Designing so as to use the best operating conditions—optimum velocity, highest possible Δt, highest allowable operating temperature.
3. Realizing that while the above is good engineering, it isn't always good food technology, and one should also strive for best processing conditions. Generally speaking, low temperatures, low Δt—and consequently large surfaces are desirable if one is to keep time down. A balance must be struck.
4. Design for a maximum ratio of heating surface to volume.
5. Consider use of scrapers.
6. Do not forget to consider pressure drop—it is always associated with heat transfer.
7. Design for minimum maintenance.
8. Design for cleanliness.
9. Remember corrosion as well as heat transfer considerations when choosing the metal used.
10. Specify A. S. M. E. design standards—you do not want jacket kettles which turn inside out.
11. Generally specify welded construction.
12. Make provision for thermal expansion stresses.
13. When using tubes, generally use those of maximum length for economy, considering cleaning and expansion, however.
14. Do not forget that gaskets are *not* sanitary—and steaming out is a poor substitute for cleanliness.
15. Provide adequate vents.
16. Apply safety valves or better devices such as rupture disks to all individual pieces of equipment.
17. Have steam chests equipped with gauge glasses and thermometer wells for checking and controlling operation.
18. Strive for uniform plant standards of design—makes for safety and ease of maintenance.
19. Insulate your equipment. Where sanitation demands it, weld on cover jackets.
20. Use good steam traps.
21. Maintain valves, traps, etc. Inspect them regularly.
22. Design equipment to facilitate inspection and maintenance.
23. Run your steam plant properly—have air free and oil free steam.
24. Consider all methods of heat transfer—not just steam although that is the lowest cost generally. Near Infra Red, Induction, Radiant and other types have their use.
25. Don't forget you can transfer heat with no transfer surface—for instance evaporative cooling is not used as much as it deserves to be.
26. On all major heating problems consider overall plant heat balance.
27. Where steam requirements are high the overall thermal efficiency of each piece of equipment should be determined and heat losses (*e.g.*, radiation) be clearly analyzed and economically appraised.

TABLE OF NOMENCLATURE

A. Area of heat transfer surface, square feet.
C_p Specific heat at constant pressure (B.t.u./(lb. fluid) (deg. F.)
D Diameter, feet.
G Mass velocity, lbs./(hr.) (sq. ft. of cross section).
h Coefficient of heat transfer between fluid and surface, B.t.u./(hr.) (sq. ft.) (deg. F.). h_1, h_2 refer to different films.
k Thermal conductivity, B.t.u./(hr.) (sq. ft.) (deg. F. per ft.).
Q/θ Rate of heat transfer, B.t.u./hour.
Δt Temperature difference across a given film or system, ° F.
U Overall coefficient of heat transfer between two streams, B.t.u./(hr.).(sq. ft.) (° F.).
X Wall thickness, feet.
μ Absolute viscosity, lbs./(hr.) (ft.).

REFERENCES

1. Dittus, F. W., and Boelter, L. M. K. Univ. of Calif. Pub. in Eng. *2*, 443 (1930).
2. International Nickel Co. Heat transfer through metallic walls.
3. McAdams, W. H. Heat Transmission. McGraw-Hill Book Co., Inc., New York (1942).

Transactions

The Council at its September 15th meeting in Chicago arrived at many decisions which will broaden and enhance the work of the Institute. Eighteen members were present and the session was largely concerned with committee reports and discussions of matters long considered important in the development of the Institute.

The question of an ACHIEVEMENT AWARD by the Institute for outstanding achievement in food technology has been considered for sometime. A report of the committee appointed by President Harvey strongly recommended that such an AWARD be established, the AWARD to be given to the company in the food processing industry which has made the greatest achievement in food technology over the immediate past two year period. A Jury of Award is to select the awardee and the first award will be given at the Annual Food Conference in Boston in June.

The Council approved the issuing of a MEMBERSHIP CERTIFICATE to be given to each member whose dues are in order. The certificate will designate type of membership and will be suitable for framing and public display.

Future local arrangements committees will be pleased to learn that a CONVENTION MANUAL has been compiled and its publication authorized by the Council. This MANUAL will include recommendations of past committees based on Food Conference experiences and should be of inestimable assistance to future committees.

The problem of the allocation of CONVENTION PROFITS has been perplexing over the years. No standardized procedure has been followed as some local sections, which have served as hosts for the annual Food Conferences, have turned over to the Institute treasury a substantial percentage of the profits, if any, while others have elected to enhance the Section treasury. The Council adopted a policy at its recent meeting that the proposed budget for each annual conference be submitted to the Council for approval and upon approval, the Institute assumes any deficit up to the amount of the budget. It was also provided that any profits accruing from a Conference be shared equally between the local section and the national Institute.

For some time many have felt that the time is opportune for an INTERNATIONAL FOOD TECHNOLOGY CONFERENCE. Approaches have been made to a large number of nations with favorable replies. The Council approved the general approach and designated that the Tenth Annual Conference, which is to be held in Philadelphia in June, 1948, be international in scope.

Since the formation of the Institute, the membership has had divided opinions with respect to the classification of members. There are those who feel that the policy of the Institute should be to establish food technology as a profession and that the qualifications of professional status for a food technologist should coincide with qualifications for full membership. There is an increasing number of members in the Institute who have an abiding opinion that all those interested in the processing and preservation of food should be eligible for some type of membership. Many committees have considered this problem and several reports have been presented to the Council for action. At its most recent meeting, the Council listened to an additional report on this subject and restudied the entire situation. After due deliberation, the Council accepted in principle the policy for the Institute that two general types of membership should be established, the first with restricted qualifications and the second with more lenient requirements and to include insofar as possible all those interested in food technology. By proceeding on this principle the restricted class of members in the Institute would have office holding privileges and this class would tend to represent a professional group of food technologists. The names for these two general classes were not decided. Several suggestions were made for the restricted class, that is, Fellow, Food Technologist, etc.; while the

general and less restricted group could be called Associate, Affiliate, Member, etc. With the advent of the journal, the classification of membership status is essential.

The Institute at present has twelve REGIONAL SECTIONS. The Council at its recent meeting voted a Charter to the Puget Sound Section which is the twelfth official Section. These REGIONAL SECTIONS are the backbone of the Institute and the Council is appreciative of its responsibility to their support and development. Other Sections are forming from various parts of the country and within a few years the Institute should have twenty or more strong functioning Sections.

The location of future food conferences of the Institute was decided by the Council. The 1947 will be held in Boston; 1948 (International) in Philadelphia; 1949 in California; and 1950 in Chicago. With the increase in size of the Institute it is necessary that long range plans be made in order that the regular food conferences be as well organized as in the past. The increase in attendance and more complicated nature of the programs and arrangements requires long time planning.

TENTATIVE PROGRAM FOR 1947 I. F. T. CONFERENCE

BOSTON, MASS. JUNE 1 - 5

Preliminary plans announced by the Committee on Programs provide for an open forum session, two general sessions, one luncheon session, one night session, and five technical sessions, of which three will be held concurrently. In addition, there will be several extracurricular activities for instruction and entertainment.

In submitting the following tentative alignment of the program items, Mr. E. S. Stateler, Chairman of the Committee on Programs, calls attention to the possibility of changes still being made in subject matter, although no major changes are anticipated.

HOTEL STATLER — SUNDAY, JUNE 1

Council Meeting	9:00 A. M.
Registration	4:00-9:00 P. M.
General Session	7:30 P. M.

MONDAY A. M., JUNE 2

General Session, Hotel Statler

Address: President E. H. Harvey
General Announcements
B. E. Proctor, Chairman, New England Section Arrangements Committee
Address: Relation of Food Technology to Company Management
Address: Relation of Technology to Sound Company Financing
Address: Making Industrial Relations Pay Dividends
Luncheon, Hotel Statler
Presentation: Achievement Award
Acceptance: Achievement Award

MONDAY P. M.

General Session, Massachusetts Institute of Technology

Address: Organization and Management of Research and Development
Address: Methods of Obtaining Costs on Research Projects
Address: Value of Industrial Research Institutes to Food Technology
Dedication of Prescott Laboratories
Inspection of M. I. T. Laboratories

MONDAY EVENING

Popular Concert
Boston Symphony Orchestra

TUESDAY A. M., JUNE 3

Technical Session, Hotel Statler

Subject: Sanitation in Food Handling and Storage

1. The Food Industry Needs Self Control
2. Recent Developments in Transportation and Storage of Raw Materials for Processing
3. Modern Methods of Treating and Packing Fresh Foods for Rapid Transport
4. What World War II Revealed in Transportation and Storage of Processed Foods

TUESDAY P. M.

Technical Session, Hotel Statler

Subject: Processing Sanitation

1. How California Instituted Sanitary Control in Food Plants
2. How to Improve Sanitary Control Through Equipment Design
   a. Cereal Products
   b. Dairy Products
   c. Fruit and Vegetable Products
   d. Liquids
   e. Meats and Meat Products
3. Detergents for Food Plants and Methods for Their Evaluation

Business Session
President E. H. Harvey presiding

Banquet Session, 7 o'clock, Hotel Statler

Presentation: Nicholas Appert Medal—C. C. Ziegler, Chairman, Chicago Section
Acceptance: Nicholas Appert Medal
Address: Review of World Food Conditions

WEDNESDAY A. M., JUNE 4

Concurrent Technical Sessions, Hotel Statler

Session I—Refrigeration and Freezing

1. Description and Evaluation of Freezing Systems
2. Factors in Deterioration of Frozen Foods
3. Preparation of Foods for Freezing
4. Continuous Pressure Blanching

Session II—Problems in Fish Technology

1. Use of Bacterio-Static Agents in Fish Handling and Processing
2. Mechanism of Spoilage in Sea Foods
3. Recent Developments in Fish By-Products
4. Modern Technics in Preservation of Fish and Fish Products

Session III—Submitted Research Papers

WEDNESDAY P. M.

Boat Excursion to Gloucester
Inspection of Gloucester Fisheries
Clam Bake and Lobster Feed at Birdseye Estate

THURSDAY, JUNE 5

Food Plant Trips—All day